Subjective Visual Vertical in Pitch and Roll in Right Hemispheric Stroke

Arnaud Saj, PhD; Jacques Honoré, PhD; Thérèse Bernat, PhD; Yann Coello, PhD; Marc Rousseaux, MD, PhD

Background and Purpose—Patients with right hemispheric stroke usually present an anticlockwise deviation of the subjective visual vertical (SVV) in the frontal (roll) plane. However, the occurrence of a similar disorder in the sagittal (pitch) plane has never been assessed. We investigated the subjective visual vertical in both planes in those patients.

Methods—Eight patients, 4 with spatial neglect (N+) and 4 without neglect (N−), were compared with 4 healthy participants (C). They sat facing a luminous bar adjustable in rotation, either in the roll or in the pitch plane, and had to orient it in a vertical position, in the dark.

Results—Compared with N− (−0.1°) and C (+1.1°) groups, N+ patients presented with a significant backward deviation (−4.5°) of the SVV in pitch. In accordance with other studies, they also showed a significant anticlockwise deviation (−8.8°) of the SVV in roll, as compared with N− (−1.9°) and C (+0.4°) subjects. This was associated with an opposite trunk deviation in both planes.

Conclusions—While confirming the anticlockwise deviation already reported in the frontal plane, we showed for the first time to our knowledge a backward deviation of the SVV in neglect patients, which has to be put in relation with their balance disorders. (Stroke. 2005;36:588-591.)

Key Words: hemispatial neglect  ■  posture  ■  stroke  ■  visual vertical

Signs of spatial misorientation are frequent after central nervous system injury. In the frontal plane (roll), abnormalities of the subjective visual vertical (SVV) have been reported after a unilateral hemispheric stroke. The deviation is most frequently contraversive, ie, anticlockwise for patients with right injury,1,2 and lesions of the vestibular cortex or of its subcortical afferences have been incriminated in this deficit.1 A link has also been suggested with the spatial neglect syndrome,3 which is more frequent and severe after right hemisphere lesions.

However, the representations of space involve other dimensions, especially the vertical orientation in the sagittal plane (pitch). This dimension has been investigated in normal subjects4 showing a “frame effect” similar to that previously reported in the frontal plane, consisting of a deviation of the SVV in the direction of the frame tilt. In the pathology, a lack of bias has been reported for the subjective postural vertical in patients with peripheral vestibular lesions.5 But nothing is known about a possible SVV deviation in patients with hemispheric lesions and neglect.

The aim of this study was therefore to investigate the SVV in the pitch and roll planes in patients with right hemisphere stroke, with and without spatial neglect. Because the SVV deviation in roll has been discussed in relation with balance disorders in the frontal plane,6 we also considered the spontaneous trunk orientation in both planes and attempted to relate postural scores with corresponding SVV deviations.

Subjects and Methods

Subjects

Eight right-handed right brain–injured patients (Oldfield Test,7 score >18/20) were recruited in the neurological rehabilitation department of Lille CHU to take part in the present research (Table). They were informed of the experimental protocol and signed an informed consent form before taking part in the study, which was conducted in accordance with the Declaration of Helsinki. All had experienced a relatively recent (1 to 3 months) hemorrhagic or ischemic stroke, demonstrated by magnetic resonance imaging 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, psychotropic treatment, and pusher syndrome (ie, severe contralateral trunk deviation with active resistance to any attempt of external correction)8 were not included in the study.

Spatial neglect was assessed using bell cancellation,9 line bisection,10 and scene copy11 tests. Four patients were considered as neglect (N+; mean age, 60.0 years) on the basis of their pathological performance in at least 2 of the 3 tests, and 4 were free of any neglect (N−; mean age, 58.5 years). Four right-handed healthy subjects (C; mean age, 49.2 years) made up a control group. The mean age of

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From the Service de Rééducation Neurologique (A.S., T.B., M.R.), Hôpital Swynghedauw, CHRU de Lille; Neurosciences Fonctionnelles et Pathologies (J.H.); FRE2726 CNRS, Université de Lille 2, CHRU de Lille; and URECA (Y.C.), Université de Lille 3, France.

Correspondence to Dr Marc Rousseaux, Service de Rééducation Neurologique, Hôpital Swynghedauw, CHRU, 59037 Lille Cedex, France. E-mail mrousseaux@chru-lille.fr

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588
controls was less than that of patients, but the between-group differences were not significant \( F(2,9) = 0.76; P = 0.495 \).

**Experimental Setup**

A metal rod (25-cm long, 1.5-cm wide, and 1.5-cm thick) positioned in a fronto-parallel plan was used to evaluate the vertical direction (Figure 1). A metal disk (25 cm in diameter), centered on the rotation axis and connected to an electronic device displayed the angle between the rod and the objective vertical (error) in tenths of degrees. The rod was covered with a phosphorescent paint so that it was visible in the dark.

The subject was in a sitting position, in front of the apparatus. The head, aligned with the trunk, was fixed by a headrest with lateral stabilizers. An abdominal strap helped to maintain a vertical position when sitting. The eyes were at a similar distance from both ends of the rod when it was vertical,\(^1\)\(^2\)\(^3\)

**Procedure**

Subjects were tested individually in a quiet, dark room. During the task, only the rod was visible and the participant had to set it to the vertical, holding it in the middle with the right arm half-extended.

Figure 1. Apparatus and patient positioning for assessing the SVV in pitch (a) and roll (b).

Time was not limited but task completion was generally fast whatever the group. The task was performed in a frontal-parallel or the sagittal plane. As compared with the former condition (roll), the task differed in the latter (pitch) in that any displacement of the rod changed its visual angular size.

In each plane, the initial tilt of the rod was \(0^\circ\), \(-45^\circ\), or \(+45^\circ\) (a negative value indicates a leftward or backward deviation of the upper tip of the rod, and a positive value, a rightward or forward tilt). A total of 60 adjustments were performed (10 trials \( \times \) 3 initial tilts \( \times \) 2 planes). The trials were separated by \( \approx 20 \) seconds and the order of presentation of the various conditions was counterbalanced. Subjects kept their eyes closed during the examiner presetting of the rod (initial tilt) and no information was provided about performance accuracy.

In the patients, the spontaneous trunk posture was given a score on a clinical scale, when sitting on the edge of a mat table, with the eye closed, and with the feet at \( \approx 15 \) cm from the ground. After a 5-minute adaptation period, the trunk posture was recorded in the frontal plane (\(-3\): severe left tilt with tendency to fall; \(-2\): moderate left tilt; \(-1\): mild left tilt; \(0\): no trunk tilt; \(1\): mild right tilt; \(2\): moderate right tilt; \(3\): severe right tilt) and in the sagittal plane (\(-\): backward tilt; \(+:\) forward tilt). The severity of the tilt was mainly estimated by the importance of the lateral or anterior-posterior deviation of the dorso-lumbar spine, ie, between the lower lumbar and the lower cervical areas.

**Statistical Analyses**

Separate analyses were performed on the angles of deviation from the objective vertical in pitch and roll planes. Student \( t \) statistic was computed to compare the mean SVV in each group to the objective vertical. ANOVAs were performed with Statistica software, using the Newman–Keuls test for post hoc comparisons.

**Results**

In pitch, the SVV (Figure 2) of N− patients \( (P=0.97) \) and C subjects \( (P=0.09) \) was not significantly different from the objective vertical, in contrast with N+ patients \( (P=0.04) \). The analysis of variance revealed a significant effect of group \( [F(2,9)=7.30; P=0.013] \). The N+ patients presented a significant deviation of the upper extremity of the rod in the backward direction (\(-4.5^\circ\)), compared with the N− (\(-0.1^\circ\); \(P=0.02\)) and C groups (\(1.1^\circ; P<0.01\) ), which did not differ
significantly ($P=0.49$). At an individual level, the backward deviation was observed for every $N^+$ patient, with scores being below the confidence interval (CI) ($P=0.05$) for all $C$ subjects, but for only 1 $N^-$ patient.

Mean individual standard deviations were as follows: $5.1^\circ$ in $N^+$ group, $5.8^\circ$ in $N^-$ group, and $1.5^\circ$ in $C$ group. The values of all the patients were above the CI ($P=0.05$) of $C$ subjects.

In roll, the SVV (Figure 3) of $N^+$ and $N^-$ patients significantly differed from the objective vertical (respectively, $P=0.04$ and $P=0.05$), whereas this was not the case for $C$ subjects ($P=0.37$). The analysis of variance also suggested a different performance in the 3 groups [$F(2,9)=10.02; P=0.005$]. $N^+$ patients inclined the rod in the anticlockwise direction ($-8.8^\circ$) more than $N^-$ patients ($-1.9^\circ; P=0.01$) or control subjects ($0.4^\circ; P<0.01$). The 2 latter groups did not differ significantly ($P=0.30$; Figure 2).

At an individual level, the anticlockwise deviation was observed for every $N^+$ patient, with scores being below the CI ($P=0.05$) for all $C$ subjects, but for only 1 $N^-$ patient.

Mean individual SDs in $N^+$, $N^-$, and $C$ groups were $2.5^\circ$, $1.3^\circ$, and $0.5^\circ$, respectively. The values of all the patients were above the CI ($P=0.05$) of $C$ subjects.

Considering all the patients (8 cases), SVV values in pitch and in roll were not intercorrelated (Spearman test; $P=0.289$) or correlated to age (respectively, $P=0.193$ and 0.976) and delay since stroke (respectively, $P=0.290$ and 0.467).

In the spontaneous sitting posture of neglect patients, a trunk tilt toward the right side, ipsilateral to the lesion, and contralateral to the SVV deviation in roll occurred in 3 of 4 cases (mean score, $+0.75$), and a forward trunk tilt contrasting with a backward SVV deviation in pitch occurred in all cases (mean score, $+1.25$). In patients without neglect, the trunk tilt in the frontal plane was toward the right side in 1 case, the left side in 2, and absent in 1 other (mean score, $-0.50$). In the sagittal plane, it was forward in 1 case, discretely backward in 1, and absent in 2 others (mean score, $-0.25$).

**Discussion**

The SVV was investigated in the frontal (roll) and sagittal (pitch) dimensions in stroke patients with neglect, and in 2 control groups including right brain–injured patients without neglect or healthy individuals. Our study provided the first observation of a backward deviation of the subjective vertical in pitch in neglect patients.

Regarding the SVV in roll, the results in the 3 groups corroborated previous investigations on right brain-injured patients, which showed an anticlockwise misalignment of greater amplitude in the neglect group.

This deviation is classically related to a disorder of the representation of the actual vertical, in relation with vestibular cortex lesions.

Our main finding was the observation that neglect patients, and to a lesser degree non-neglect patients with right hemispheric lesion, presented with a backward deviation of the SVV. The task appeared more difficult in the pitch than in the roll condition, as suggested by the greater individual variability recorded in the 3e groups, and different weighting between visual cues and somatosensory information arising from the fingers cannot be excluded. Despite this increased difficulty, the mean backward error of the patients seemed less severe than the anticlockwise misalignment in the frontal plane. These differences between the 2 tasks can be related to specificities at the visual level. When adjusting the rod in the frontal–parallel plane, the orientation of the rod can be directly evaluated from the orientation of its retinal projection. By contrast, processing orientation in the sagittal plane requires information about depth, because rod orientation can be perceived only through variations of the apparent length of the rod or of the width of its extremities. The nearer extremity appears optically larger and the linear perspective regularly varies with the inclination.

In fact, right brain–damaged patients proved to present with deficits in judgements about shapes and angles or other tasks requiring the integration of visual cues to depth. Be that as it may, even though the mechanisms could differ, the SVV deviations in both planes are the consequences of altered representations related to the lesion of cortico–subcortical systems that elaborate these representations.

The anticlockwise deviation of the SVV in roll was associated with an opposite and right tilt of the body in 3 of 4 neglect patients. When standing upright, a trunk tilt to the side of the lesion has been frequently reported in nonpusher patients with hemispheric stroke, which was

![Figure 2. Subjective visual vertical in pitch plane as a function of the group. Severe backward deviation in patients with neglect ($N^+$) as compared with patients without neglect ($N^-$) and control subjects ($C$).](image)

![Figure 3. Subjective visual vertical in roll plane as a function of the group: severe anticlockwise deviation in patients with neglect ($N^+$) as compared with patients without neglect ($N^-$) and control subjects ($C$).](image)
more severe after right-sided lesion. Thus, we confirmed the phenomenon in a sitting position. The opposite effects of neglect on SVV in roll and posture evoke the E-effect\textsuperscript{18} observed in healthy subjects: a mild lateral tilt of the body was found to bias the SVV in the opposite direction. This has also been observed by Mertz and Lepecq\textsuperscript{19} with an imaginary tilt, ie, the mere instruction to imagine a body tilt. Furthermore, in neglect patients, the backward deviation of the SVV contrasted with a forward body tilt. The observation that neglect patients show an opposite deviation of SVV and body tilt, in both the frontal (roll) and sagittal (pitch) planes, is hardly compatible with the hypothesis that they would tend to spontaneously place their trunk in the direction of the subjective vertical.\textsuperscript{6} Besides, these deficits could be related aspects of a same representational deficit. This view differs from what happens when lower levels of the brain are lesioned, because dissociation between SVV and postural deficits frequently occur then.\textsuperscript{20}

In conclusion, this study showed that patients with right hemispheric lesion and spatial neglect both present with an anticlockwise and a backward deviation of the SVV, and that in a usual sitting position, these errors are associated with opposite trunk tilts. Such disorders can help to explain the severity of their imbalance,\textsuperscript{21} which has deleterious consequences on the late functional recovery.

References

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