Are Rotations in Perceived Visual Vertical and Body Axis After Stroke Caused by the Same Mechanism?

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Background and Purpose—The aim of this study was to investigate whether allocentric and egocentric coordinate systems are congruently biased after hemisphere stroke, which would suggest a single underlying mechanism.

Methods—The perception of the long body axis (LBA), an egocentric reference, and that of the subjective visual vertical (SVV), an allocentric reference, was assessed in both the upright position and with 30° lateral body tilts in 15 patients with a hemisphere stroke and 12 control subjects.

Results—In control subjects, estimates were accurate in upright but rotated in tilted positions (LBA 7°±6° overestimation and SVV 8.8°±7.8° toward the body). In patients, SVV (−4.4°±4.6°) and LBA (−4.8°±5.3°) were congruent in upright positions and when patients were ipsilesionally tilted (1.5°±7° and 1.9°±7°, respectively). In contrast, SVV and LBA were dissociated when the body was tilted to the contralateral side with overestimation of the LBA (−9.2°±4.6°) but no effect on SVV (−4.1°±6.4°).

Conclusions—Because rotations in egocentric and allocentric reference systems found after stroke are differently modulated by lateral tilts, they are not due to a single underlying mechanism. However, they share common bases and can be simultaneously reduced by ipsilesional body tilt. Differences in the way somesthetic information is integrated may explain the differences in LBA and SVV. (Stroke. 2008;39:3099-3101.)

Key Words: longitudinal body axis ■ pushing ■ spatial representation ■ stroke ■ subjective visual vertical

Perception of both the subjective visual vertical (SVV) and the longitudinal body axis (LBA) may be rotated to the contralateral side after hemisphere stroke. It is not known whether these biased perceptions are affected congruently. Congruency of allocentric (SVV) and egocentric (LBA) coordinate systems would suggest a single underlying mechanism, whereas dissociation would imply independent mechanisms. Accordingly, this study investigated the LBA and SVV concurrently in patients with hemisphere stroke and in healthy subjects. Various positions of lateral tilt were used to modulate SVV and LBA in an attempt to trigger dissociations.

Materials and Methods

Subjects

Inclusion criteria consisted of first and unique hemisphere stroke. Exclusion criteria consisted of unstable status, neuropathy, psychiatric disorders, or problems of comprehension due to aphasia or dementia.

Fifteen patients with hemisphere stroke (Table 1) matched with 12 healthy subjects gave informed consent to take part in the study according to the guidelines of the local ethics committee. None of patients presented signs of vestibular loss according to clinical tests (no dizziness or spontaneous nystagmus). Visual field defects were sought by Goldman perimetry. One patient showed contraversive pushing. Clinical features are presented in Table 2.

Tasks

The SVV and LBA were assessed in complete darkness by visual adjustments of the direction of a luminous line (15 cm long, 2 mm wide, 1.5 m from the subject). Subjects indicated verbally how to reset the line to their SVV or the LBA. The subjects’ head, trunk, and lower limbs were restrained in an upright sitting position within a tilting drum. The LBA and the SVV were investigated in the upright posture (0°, tested first) and in lateral body tilts of 30° to both sides. The order in which the SVV versus LBA estimates were obtained was randomized across conditions and subjects. The initial orientation of the luminous line was either 30° or −30° and the order randomly distributed over the 10 trials by condition.

The error in degrees of perceptual estimates relative to the objective orientation of the LBA or gravitational upright was used as the dependent measurement for all analyses. Errors (relative to SVV and LBA) were analyzed together because both were estimated with the same device (same procedure and same units and accuracy of measurement; only the instructions [LBA/SVV] were different). A negative value for both SVV and LBA corresponded to a rotation relative to the objective direction (true vertical or objective LBA) toward the left shoulder for control subjects and toward the contralateral side for patients (after sign transformation according to the lesion side).
Table 1. **Group Characteristics (mean±SD)**

<table>
<thead>
<tr>
<th></th>
<th>Control Subjects</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>53.3 (±11.4)</td>
<td>54.7 (±10.6)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>67 (±14)</td>
<td>64 (±10.1)</td>
</tr>
<tr>
<td>Height, cm</td>
<td>167.5 (±8.8)</td>
<td>170 (±8)</td>
</tr>
<tr>
<td>Gender</td>
<td>M 5 F 7</td>
<td>11 M 4 F</td>
</tr>
</tbody>
</table>

M indicates male; F, female.

Statistical Analysis

An analysis of variance was performed on mean errors relative to the objective directions with group as the between-subject factor (control subjects, patients) and body position (−30°, 0°, +30°) and task (SVV, LBA) as the within-subject factors. Post hoc analyses used Tukey’s honestly significant difference and, when needed, Student t test and Pearson’s correlations were computed. The α risk was P=0.05. The statistical power (Pw) is given for each comparison.

Results

The analysis of variance group*body position*task revealed a major group effect (F[1,25]=5.45; P=0.027; Pw=0.9), a body position effect (F[2,50]=34.44; P<0.001; Pw=0.9), an interaction between group and body position (F[2,50]=4.49; P=0.016; Pw=0.9), and between task and body position (F[2,50]=4.21; P=0.021; Pw=0.9), but no task effect (F[1,25]=2.75; P=0.10; Pw=0.8) or interaction between task and group (F[1,25]=0.83; P=0.37; Pw=0.4) or interaction between the 3 variables (F[2,50]=0.5; P=0.6; Pw=0.9; Figure).

Influence of Body Position and Task in Patients

Post hoc tests showed that compared with the upright position, ipsilesional body tilts led to ipsilesional rotations of the LBA (P=0.0035), whereas contralesional body tilts led to contralesional rotations of the LBA (P=0.008). There were no differences in SVV estimations when patients were upright or tilted to the contralesional side (P=0.99), whereas an ipsilesional body tilt led to ipsilesional rotation of the SVV with respect to estimations when upright (P<0.001).

During a contralesional body tilt, estimations of both SVV (t[14]=2.44; P=0.028; Pw=0.9) and LBA (t[14]=4.64; P<0.001; Pw>0.9) were different from the norm 0° (true vertical), whereas this was not the case during ipsilesional body tilt (SVV: t[14]=0.79; P=0.444; Pw=0.5; LBA: t[14]=1.02; P=0.328; Pw=0.6).

Relationship Between Subjective Visual Vertical and Long Body Axis Perception in Control Subjects and Patients

For control subjects, SVV and LBA estimations correlated significantly in both the “upright” (r=0.96; P<0.001) and “body tilt” conditions (tilt toward subjects’ right: r=0.75; P=0.005; tilt toward subjects’ left: r=0.59; P=0.03). For patients, SVV and the LBA estimations correlated when upright (r=0.91; P<0.001) and tilted toward the ipsilesional side (r=0.59; P=0.02) but not when tilted toward the contralesional side (r=0.18; P=0.507).

Discussion

The present study confirms that lateral tilt normally causes rotations of SVV and LBA in the direction of the body position with an overestimation of the body tilt. The key novel findings are: (1) when seated upright, patients with hemisphere stroke can display similar contralesional rotations of both SVV and LBA perception. We also show in upright patients that SVV and LBA are correlated; (2) for ipsilesional tilt, the SVV shifted toward 0°. This shift could be interpreted as the result of an Aubert effect (rotation of the SVV in the direction of the body position5) superimposed on the pre-

Table 2. **Clinical Characteristics of Upright Patients**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Gender/Age, Years</th>
<th>Etiology</th>
<th>Lesion Side</th>
<th>Time Since Stroke Onset, Months</th>
<th>Lesion Location</th>
<th>Visual Field Defect</th>
<th>SVV Upright Patient, °</th>
<th>LBA Upright Patient, °</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 1</td>
<td>F/60</td>
<td>I</td>
<td>R</td>
<td>2</td>
<td>F/R/P/T/CR/S</td>
<td>No</td>
<td>−6.2</td>
<td>−6.1</td>
</tr>
<tr>
<td>P 2</td>
<td>M/64</td>
<td>I</td>
<td>L</td>
<td>4.7</td>
<td>F/T/CR/S/L</td>
<td>No</td>
<td>−2.3</td>
<td>−3.8</td>
</tr>
<tr>
<td>P 3</td>
<td>M/52</td>
<td>I</td>
<td>L</td>
<td>3.7</td>
<td>F/R/P/T/CR/S/L</td>
<td>No</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>P 4</td>
<td>M/49</td>
<td>I</td>
<td>R</td>
<td>1</td>
<td>P/CR</td>
<td>No</td>
<td>−5.3</td>
<td>−4.9</td>
</tr>
<tr>
<td>P 5</td>
<td>M/63</td>
<td>I</td>
<td>R</td>
<td>3.4</td>
<td>F/R/CR/P</td>
<td>No</td>
<td>−8</td>
<td>−8.2</td>
</tr>
<tr>
<td>P 6</td>
<td>M/67</td>
<td>I</td>
<td>R</td>
<td>7</td>
<td>F/R/P/T/CR/S/L/T</td>
<td>No</td>
<td>−17.7</td>
<td>−19.4</td>
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<tr>
<td>P 7</td>
<td>M/50</td>
<td>H</td>
<td>L</td>
<td>2.3</td>
<td>CR/S/L/T</td>
<td>No</td>
<td>−6.2</td>
<td>−5.6</td>
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<tr>
<td>P 8</td>
<td>F/30</td>
<td>I</td>
<td>L</td>
<td>6</td>
<td>F/R/P/T/CR/S/L</td>
<td>No</td>
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<tr>
<td>P 9</td>
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<td>H</td>
<td>L</td>
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<td>CR/S/L/T</td>
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<tr>
<td>P 10</td>
<td>F/52</td>
<td>I</td>
<td>R</td>
<td>1.3</td>
<td>F/R/P/T/CR/S/L</td>
<td>Yes</td>
<td>−7.1</td>
<td>−9.6</td>
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<tr>
<td>P 11</td>
<td>M/67</td>
<td>H</td>
<td>R</td>
<td>1.2</td>
<td>O/S/IC/T</td>
<td>Yes</td>
<td>−3.8</td>
<td>−9.5</td>
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<tr>
<td>P 12</td>
<td>M/54</td>
<td>H</td>
<td>R</td>
<td>2.9</td>
<td>CR/S/L/T</td>
<td>No</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>P 13</td>
<td>F/61</td>
<td>I</td>
<td>R</td>
<td>4</td>
<td>T/CR/L</td>
<td>Yes</td>
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<tr>
<td>P 14</td>
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<td>H</td>
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<td>CR/S/L/T</td>
<td>No</td>
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<td>P 15</td>
<td>M/57</td>
<td>H</td>
<td>R</td>
<td>3</td>
<td>L/T</td>
<td>No</td>
<td>−2</td>
<td>1.7</td>
</tr>
</tbody>
</table>

*Patient with strong contraversive pushing.
F indicates female; M, male; I, ischemia; H, hematoma; R, right; L, left; F, frontal cortex; T, temporal cortex; P, parietal cortex; O, occipital cortex; R, Rolandic cortex; CR, corona radiata; S, striatum; T, thalamus; IC, internal capsule. SVV estimations after left or right lesion did not differ (t[13]=0.96; P=0.1). The same was found for LBA estimations (t[13]=1.16; P=0.065).
existing SVV tilt with the patient upright. The construction of this reference is based on multisensory integration, and its recalibration is probably due to overweighting of the somatosensory contribution to gravity perception, whereas the contribution of the otoliths remains constant. Because the mean interval between stroke and vertical testing was 3 months, mechanisms of plasticity and compensation had probably already occurred, but our results showed that the perceptual dysfunction had not resolved and could be modulated by ipsilesional tilts; (3) for contralesional tilt, toward the hypesthetic side, there was little change in the SVV rotation present in the upright position, whereas this was not the case for LBA, which showed an effect. This difference in the perception of the SVV and LBA with lateral tilt could arise because modulation of the LBA may crucially depend on the integrity of the somesthetic information linked to general propiosomaesthetic cues (body schema) whatever the side of tilt. In contrast, SVV may be influenced by lateralized somesthetic information. The one patient with pushing in the study was similar to the other patients, all of whom had contralesional rotations of both LBA and SVV in the upright position; pushing cannot be explained by a tilted SVV, a tilted LBA, or a mismatch between LBA and SVV perceptions.

Because rotations in egocentric and allocentric references after stroke are differentially modulated by lateral tilts, it is unlikely that they derive from a single underlying mechanism. However, they remain robustly linked in upright patients revealing that they share common bases, probably in relation with the construction of coordinate systems. Both can be simultaneously reduced by an ipsilesional body tilt. This result could have implications in rehabilitation because perception of verticality of both the self and external visual objects is important for the control of posture and motion.

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Disclosures
None.

References
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