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## Interpreting spatial dysgraphia after stroke: straight-ahead of straight above

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## Introduction

Spatial dysgraphia, frequently observed after a right hemisphere stroke (1), associates signs of spatial compression in relation to spatial neglect, and a tilted writing which remains to be explained. Here we present a case study showing that tilted writing is due to a tilted representation of the vertical.

## Materials and Methods

### Case presentation

JW was a 75 year-old male, right-handed, who underwent a hemorrhagic right hemisphere stroke causing a total left hemiplegia with pronounced hemianesthesia, left hemianopsia and signs of unilateral spatial neglect (UNS). At entry, balance disorders were particularly severe, with a pusher syndrome. Stroke also induced a spatial dysgraphia characterized by a counterclockwise tilt of the writing lines (Fig. 1).

### Handwriting evaluation

- **Tasks:** Copy of the 5 first lines of the BHK test, at M3 and M9, and after modulation of verticality representation (M3). Several types of cueing were tested: blank paper (reference condition) and spatially indexed paper (12° or 24° upwardly or downwardly sloping lines).
- **Parameters analysed:** inclination of each writing line in respect to Earth vertical (°) or to the cueing lines, inclination of the left-hand margin in respect to the Earth vertical, and the mean time to write a letter (sec).
- **Statistics:** comparison of JW's results with a peered healthy participant (JB).

### Representation of the verticality

- Postural vertical (VP) [2]
- Visual vertical (VV) [3]
- Modulation: tilt for 10 minutes at 30° in the dark

### UNS

Body and non-body UNS evaluation using a battery of well-known tests.

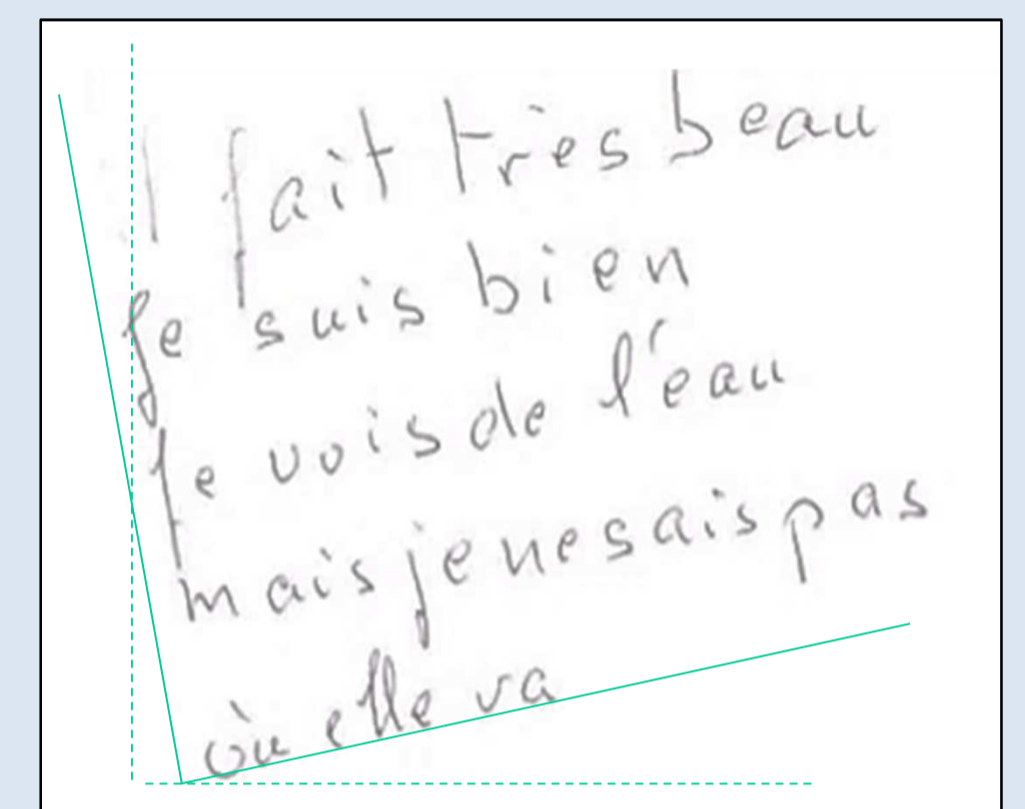


Figure 1. Sample of JW's handwriting at M3 on blank paper.

## Results

	JB	JW-M3	JB vs. JW-M3	JW-M9	JB vs. JW-M9	JW-M3 vs. JW-M9
<b>Blank paper</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	-2.1	-9.4	0.008*	-8.8	0.008*	0.08
IQR (°)	1.2	4.6		1.4		
<b>Lines down 24°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	-0.9	-10.2	0.008*	-8.2	0.008*	0.548
IQR (°)	2	5.7		3.5		
<b>Lines down 12°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	-1	-3.5	0.008*	-4.4	0.008*	0.89
IQR (°)	1.7	3.9		1.9		
<b>Lines up 12°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	0	-1.8	0.016	-0.6	0.016	0.08
IQR (°)	0.7	2.1		1		
<b>Lines up 24°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	-1.1	-0.3	0.548	-1	0.222	0.04
IQR (°)	1.4	1.2		1.1		

Table 1. Inclination of JW's writing lines at M3 and M9 in the different conditions.

	JB	JW-M3	JB vs. JW-M3	JW-M9	JB vs. JW-M9	JW-M3 vs. JW-M9
<b>Tilt of the left-hand margin</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	-0.1	-9.4	0.008*	-8.5	0.008*	0.416
IQR (°)	2.2	4.6		1		
<b>Angle between the margin and the writing lines</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (°)	92	90	0.102	91	0.129	1
IQR (°)	1	2		1		

Table 2. Tilt of JW's left-hand margin and writing orthogonality at M3 and M9 in the 'blank paper' condition.

	JB	JW-M3	JB vs. JW-M3	JW-M9	JB vs. JW-M9	JW-M3 vs. JW-M9
<b>Blank paper</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (sec/lett)	0.9	1.7	0.008*	0.9	0.548	0.008*
IQR (sec/lett)	0.3	0.7		0.4		
<b>Lines down 24°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (sec/lett)	0.7	1.5	0.008*	0.8	0.151	0.008*
IQR (sec/lett)	0.2	0.2		0.3		
<b>Lines down 12°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (sec/lett)	0.7	1.4	0.008*	0.8	0.222	0.008*
IQR (sec/lett)	0.3	0.8		0.2		
<b>Lines up 12°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (sec/lett)	0.7	1.4	0.016	0.9	0.095	0.008*
IQR (sec/lett)	0.3	0.7		0.2		
<b>Lines up 24°</b>			<i>p</i>		<i>p</i>	<i>p</i>
median (sec/lett)	0.7	1.1	0.032	0.8	0.222	0.222
IQR (sec/lett)	0.3	0.5		0.4		

Table 3. JW's handwriting speed at M3 and M9 in the different conditions.

	Before modulation	After modulation	<i>p</i>
<b>Postural vertical</b>			
mean (°)	-9.8	0.6	0.001*
SD (°)	3.6	3.7	
<b>Writing lines inclination</b>			<i>p</i>
median (°)	-9.4	-5.2	0.043*
IQR (°)	4.6	2.7	
<b>Tilt of the left-hand margin</b>			<i>p</i>
median (°)	-9.4	-3.2	0.008*
IQR (°)	4.6	4.4	
<b>Angle b/w the margin and the writing lines</b>			<i>p</i>
median (°)	90	92	0.279
IQR (°)	2	1	
<b>Writing speed</b>			<i>p</i>
median (sec/lett)	1.7	0.9	0.008*
IQR (sec/lett)	0.7	0.1	

Table 4. Spatial and temporal features of JW's handwriting after verticality normalization.

- **Inclination of handwriting** lines on blank paper and downward sloping lines, both at M3 and M9 (Tab.1)
- No significant line inclination on upwardly sloping lines (Tab.1)
- **Inclination of the left-hand margin** on blank paper at M3 and M9 and conservation of the orthogonality (Tab.2)
- **Writing speed slower than the healthy subject** at M3 but no longer at M9 (Tab.3)
- Signs of UNS at M3 but not M9 (not shown)
- Verticality representation: altered at M3 and M9 (not shown)
- Lines inclination, margin tilt and writing speed **clearly improved after PV normalization** (Tab.4)

## Discussion and Conclusion

At 3 months, JW's handwriting was slow and presented an upward tilt and an increased left-hand margin due to a global tilt of his orthogonal scheme. The spatial features of his handwriting were maintained 9 months after stroke, while his writing speed was normalized. JW's handwriting inclination was neither related to spatial neglect nor to a rotated straight-ahead, but was clearly improved by a transient modulation of JW's verticality perception.

**After stroke, a tilted handwriting may thus be due to a tilted representation of the vertical.**

## References

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