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The relationship between visual orienting and interlimb synchrony in a patient with a superior parietal infarction: A case study

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Lesions of parietal cortex sometimes produce visual or proprioceptive deficits that manifest in various forms of neglect or extinction¹, conditions that often persist in the post-acute phase of stroke^{2,3} and that have been demonstrated to impede functional recovery^{4,5,6,7}. Most likely due to the heterogeneity of patient populations, limited evidence exists for the effectiveness of interventions that maximize a patient's potential for using alternative sensory modalities to increase awareness of or attention to the under-represented sensory fields⁴, a strategy that *should* facilitate sensorimotor rehabilitation. Moreover, few studies, if any, have addressed the utility of such an approach in improving interlimb coordination. Here we report the case of a stroke patient with an extensive left parietal lesion that resulted in a contralesional proprioceptive deficit accompanied by visual extinction of the right hemi-field. Evaluation of this subject's performance on a bimanual joystick task demonstrates that visual feedback exacerbates the effects of visual extinction at the expense of the right limb, and thereby detracts from interlimb synchrony. However, when visual attention is redirected toward the right hemi-field, visual feedback compensates for inadequate proprioceptive input and thereby improves spatial accuracy of the contralesional limb. These results underscore the importance of individualizing rehabilitative strategies to accommodate existing sensory or cognitive deficits in order to maximize the potential for motor recovery.

Case Report

The subject was seated at a table in which two joysticks were mounted, one five inches to the left and the other five inches to the right of body midline (Fig. 2A). She operated the joysticks with the respective limbs in order to acquire left-right target pairs presented on a video monitor in front of her. Two cursors indicating limb positions also appeared on the monitor and served as visual feedback. The left target of the first pair appeared at (−6,0) in visual degrees, while the right appeared simultaneously at (6,0). Once the subject acquired these targets and held them for 500ms, the first (starting target) pair disappeared and a second (goal target) pair appeared in relatively peripheral locations. The appearance of the goal targets was the subject's cue to move the limbs/cursors as quickly and directly as possible from starting to respective goal targets. Each goal target was equidistant (3°) from the corresponding starting target, but varied in direction, and thus randomly elicited one of the six bimanual movement patterns depicted in Figure 2B.

Evaluation of eye parameters during performance of this task revealed an ipsilesional leftward saccade bias, reflecting visual extinction of the right hemi-field⁴. The first saccade during each of the six bimanual movement patterns was generated approximately 500ms following starting target presentation (Fig. 3A, left panel, asterisks), and was invariably directed to the left. The mean direction and variance of this saccade, averaged across all six trial types, is displayed in Figure 3B (top), and the average position of the eye (in video monitor coordinates) *at the end* of the first saccade is plotted for each of the six trial types *individually* in Figure 3C (top). The second saccade occurred, on average, around the time of goal target presentation, and the third around limb movement onset (Fig. 3A, right panel, asterisks). These saccades were directed to the right (Fig. 3B, middle) and then again to the left (Fig. 3B, bottom), respectively. Interestingly, the average eye position at the end of the second and third saccades was furthest to the left during movements 1–3 (Fig. 3C, middle and bottom, compare filled to open circles), movements in which the left goal target was presented at the greatest leftward eccentricity. This effect was particularly evident during trials in which visual feedback was provided, and corresponded with a delay in right limb reaction times. The resulting disruption of interlimb synchrony at movement onset can be seen in Figure 3A (right panel), in which the reaction times of the left (open triangles) and right (open squares) limbs are plotted during each of the six bimanual movement patterns; right reaction times were much longer than left reaction times during movements 1–3, but not during movements 4–6. The effect is even more apparent in Figure 4A, which displays reaction time interlimb intervals for movements 1–3 (600–700ms) and 4–6 (100–200ms). In contrast, reaction time interlimb intervals were not differentially influenced between bimanual patterns when the movements were performed in reverse, with the goal targets located more centrally and within closer proximity to one another. Instead, the subject's contralesional proprioceptive deficit compromised accuracy of the right limb trajectory when trials were performed *in reverse without visual feedback*, as indicated by high curvature scores reflecting the distance in visual degrees between prescribed (straight) and actual trajectories (Fig.4B). Right limb trajectories were not thus impaired, however, during the original center-out trials or reverse trials performed *with* visual feedback.

Discussion

Visual feedback detracted from interlimb synchrony at movement onset yet improved accuracy of the contralesional limb trajectory during bimanual task performance in a patient presenting with right visual extinction and proprioceptive impairments. Whereas previous studies have demonstrated that stimulus features such as size, brightness, loudness and duration can influence the manifestation of extinction¹, we demonstrate that *eccentricity* is also a critical factor; the leftward saccade/eye positioning bias was exaggerated when the left goal target was presented at greater leftward eccentricities, and only then did it delay reaction times of the right limb. This delay was most likely due to inadequate proprioceptive feedback combined with the lack of visual attention, which was initially directed to the left and thus rendered the subject incapable of assessing the position and planning the trajectory of the right limb. The resulting increase in reaction time interlimb intervals was most pronounced in the presence of visual feedback, however it was also present, to a lesser extent, without visual feedback, as well as when the subject was required to fixate on a central target throughout the trial. These results indicate the coordinative deficit arose from a combination of inadequate proprioception and a shift in *visual attention*, rather than from the leftward eye movement per se, and that perhaps visual attention was more readily shifted in the presence of visual feedback. Although visual extinction did not influence movement initiation of the limbs when the bimanual movements were performed in reverse (and goal targets were presented at lesser eccentricities), the right limb had a great deal of difficulty adhering to its prescribed trajectory during these trials. This manifestation of the contralesional proprioceptive deficit most likely occurred because starting target locations

varied from trial to trial during the reverse task, making it more difficult for the subject to become familiar with the initial position of her right limb, and to subsequently determine the direction of movement required for successful goal target acquisition. This deficit was not present when visual feedback was available, suggesting the subject was able to compensate. Taken together, these results demonstrate the need for therapeutic techniques that minimize the effects of existing deficits while maximizing the potential for cross-modal re-entrainment of, or compensation for, neural networks mediating spatial cognition in order to achieve optimal motor performance⁸.

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References

1. Mesulam, M-M. Attentional networks, confusional states and neglect syndromes. In: Mesulam, M-M., editor. *Principles of behavioral and cognitive neurology*. Oxford: Oxford University Press; 2000. p. 174-256.
2. Farne A, Buxbaum LJ, Ferraro M, Frassinetti F, Whyte J, Veramonti T, Angeli V, Coslett HB, Ladavas E. Patterns of spontaneous recovery of neglect and associated disorders in acute right brain-damaged patients. *J Neurol Neurosurg Psychiatry*. 2004; 75:1401–1410. [PubMed: 15377685]
3. Katz N, Hartman-Maeir A, Ring H, Soroker N. Functional disability and rehabilitation outcome in right hemisphere damaged patients with and without unilateral spatial neglect. *Arch Phys Med Rehabil*. 1999; 80:379–384. [PubMed: 10206598]
4. Luaute J, Halligan P, Rode G, Rossetti Y, Boisson D. Visuo-spatial neglect: A systematic review of current interventions and their effectiveness. *Neurosci Biobehav Rev*. 2006
5. Gialanella B, Monguzzi V, Santoro R, Rocchi S. Functional recovery after hemiplegia in patients with neglect: The rehabilitative role of anosognosia. *Stroke*. 2005; 36:2687–2690. [PubMed: 16269649]
6. Jehkonen M, Ahonen JP, Dastidar P, Koivisto AM, Laippala P, Vilkki J, Molnar G. Visual neglect as a predictor of functional outcome one year after stroke. *Acta Neurol Scand*. 2000; 101:195–201. [PubMed: 10705943]
7. Kalra L, Perez I, Gupta S, Wittink M. The influence of visual neglect on stroke rehabilitation. *Stroke*. 1997; 28:1386–1391. [PubMed: 9227688]
8. Halligan PW, Fink GR, Marshall JC, Vallar G. Spatial cognition: Evidence from visual neglect. *Trends Cogn Sci*. 2003; 7:125–133. [PubMed: 12639694]

Figure 1.

Left parietal infarction. (a) A representative axial slice from a T2-weighted MRI performed within 1 week of stroke onset; hyperintensity is consistent with an infarct in the left superior parietal cortex, both on the medial wall and the hemispheric convexity. The infarct is not restricted to this region, however, as there is variable involvement more anteriorly. (b) Coronal fluid attenuation inversion recovery slice showing depth of lesion, which extends into inferior parietal lobe.

Note: Images displayed in radiological orientation.

A.

B.

Movement	Left	Right
1	←	→
2	←	←
3	←	↑
4		↑
5		↑
6		↑

Figure 2.

(A) Schematic of apparatus. A pair of left-right targets were displayed on a video monitor in front of the subject. The subject acquired these targets using a pair of left-right joysticks mounted in a table (not shown) at which she was seated. After the subject held the starting targets for 500ms, they disappeared and a separate pair of left-right goal targets were displayed, instructing the subject to move as quickly and directly as possible from starting to respective goal targets. Dashed arrows near joysticks and on video monitor depict direction of limb movements and corresponding cursor movements, respectively, required for successful goal target acquisition. See text for details. (B) Schematic representation of the six bimanual movements, or trial types, performed by subjects.

Figure 3.

(A, left) Average onset time of the first saccade made during each trial type (asterisks) aligned on *starting* target presentation (filled circles). (A, right) Average onset time of the second and third saccades (asterisks), as well as of the left (open triangles) and right (open squares) limb movements, aligned on *goal* target presentation (filled circles). (B) Polar plots indicating the mean direction and variance (longer arrow = less variance) of the first (top), second (middle) and third (bottom) saccades averaged across trial types. (C) Mean position of the eye following the first (top), second (middle) and third (bottom) saccades during movements 1–3 (filled circles) and 4–6 (open circles).

Figure 4.

(A) Reaction time interlimb intervals for each of the six movements produced during the original center-out task version. (B) Curvature scores, reflecting accuracy of trajectory for the left (solid line) and right (dotted line) limbs, during reverse trials performed with and without visual feedback.