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From both sides now: crossover effects influence navigation in patients with unilateral neglect

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► Information on the wheelchair assessment course is published online only at http://jnnp.bmj.com/content/vol79/issue4

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ABSTRACT

Unilateral neglect is a challenging disorder that pervades a range of behaviours following stroke and hampers recovery. Although a preponderance of clinical studies measure performance on a range of bedside assessments, including line bisection and cancellation tasks, there have been calls for studies to embrace more relevant functional measures. Here, for the first time, we present data from two separate tasks that characterise the performance of seven patients with unilateral neglect when navigating a power wheelchair. The tasks involved negotiating an obstacle course and steering a central path between gaps of different sizes. Results from the obstacle course confirmed the clinical observation and predicted bias of contralesional errors. However, the second task revealed a robust "crossover" effect. Patients deviated to the ipsilesional side for large gaps but deviated increasingly contralesionally when steering through small gaps in behaviour that was analogous to that previously shown on line bisection tasks. Contrary to being seen as an unintuitive finding, further analysis of these errors suggests that patients are giving disproportionate weight to the location of the ipsilesional object when plotting a midline course between two objects. Our results provide a platform for further studies to investigate the modulation and rehabilitation of this important skill.

The unwieldy syndrome of unilateral neglect following stroke encompasses a range of cognitive deficits, creating difficulties in the detection of sensory information and in the production of movement on the side opposite a brain lesion, as well as non-lateralised difficulties in sustaining attention. Although the sometimes bizarre nature of behaviour shown by those affected is often considered unusual, deficits related to the syndrome are surprisingly common, with the majority of all stroke patients being affected initially[1] and around half of those with right hemisphere damage who undergo rehabilitation remaining affected.[2] Additionally, neglect has provided the opportunity to study related cognitive processes, resulting in an extraordinary interest from the neurosciences[3] and its remarkably impressive ability to predict poor outcome[2] has dictated its position as a primary focus for rehabilitation research.

When attempting to regain independent mobility following stroke, patients with neglect may be considered to be the victims of a "double whammy". First, the restoration of normal function (walking) is relatively unlikely due to the limiting influence of neglect, and second, compensatory forms of mobility (eg, a power wheelchair) are not normally available as patients are either considered, or found, to be unsafe navigating around their environment.

This study considered the issue of power wheelchair navigation in patients with neglect. Such "functional" or "real life" measures of behaviour are not only of clinical relevance but can be informative regarding the nature of cognitive processes. It may also be the case that performance on standard tests may translate and have relevance for functional behaviour. For example, some functional tasks may emphasise other requirements (eg, safety), which may modulate behaviour in a manner that has not been demonstrated on standard neuropsychological tests. However, performance on standard neuropsychological tests (eg, line bisection) may translate to have relevance for functional behaviour (eg, navigating through doorways).

This study investigated the performance of patients with neglect when steering a power wheelchair on two tasks. The first, an obstacle course, aimed to replicate findings from a previous study in which patients used a manual wheelchair.[4] The second, a finer-grained novel task involving patients steering a central path between gaps of different sizes, was motivated by the consistent finding of "crossover" when patients with neglect complete line bisection tasks. Crossover—a behaviour that has hitherto been primarily of theoretical interest—refers to the consistent finding that patients with neglect bisect a line ipsilesionally to the true centre, but as lines presented become shorter, patient bisections shift contralesionally such that they "crossover" for the shortest lines. Although numerous accounts for this crossover exist,[5–7] we were interested in whether the "functional analogue" of wheelchair navigation between different-sized gaps would reveal similar behaviour and perhaps contribute to our understanding of the crossover phenomenon.

METHODS

Patients

A total of seven patients showing evidence of unilateral neglect gave informed consent to participate in the study, in line with local ethical procedures. Patients either demonstrated neglect on established clinical tests (eg, star cancellation and line bisection[8]) or on more sensitive laboratory-based assessment (valid vs invalid cue paradigm[9]), indicating a range of severity in neglect behaviour across the patients. Lesions were confirmed by either MRI or CT scan. All patients with the exception of RH had right hemispheric lesions and resulting left-sided neglect. RH had a left hemispheric lesion and resulting right-sided neglect. Lesion sites were heterogeneous and involved cortical and subcortical structures that

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Table 1 Details of patient characteristics and assessment information

Patient	Age (y)	Years since stroke	Hemisphere	Neglect on cancellation task	Neglect on line bisection	Neglect on lab-based task	Hemi-anopia	WAC completed	DAT completed
JB	72	6	R	No	No	Yes	No	Yes	Yes
RH	74	7	L	No	No	Yes	Yes	No	Yes
MP	53	12	R	Yes	Yes	Yes	No	Yes	Yes
RT	58	2	R	Yes	Yes	Yes	Yes	Yes	No
TM	68	4	R	Yes	Yes	Yes	No	Yes	Yes
JP	72	1	R	Yes	Yes	Yes	No	Yes	Yes
AS	73	3	R	No	Yes	Yes	No	Yes	Yes

DAT, doorway accuracy test; L, left; R, right; WAC, wheelchair assessment course.

are typical of the neglect population.[10] Further information regarding the patients can be found in table 1.

Procedure

Navigation performance was assessed on two tasks: the wheelchair assessment course (WAC) and the doorway accuracy test (DAT). Prior to commencing the tasks, all patients had a short period of training. This involved an "introduction" to the chair and its operation, followed by a period of familiarisation with the joystick control. All patients were quickly able to use the joystick control appropriately and then spent 5–10 minutes having a "test-drive" in the corridor used for the WAC but without the obstacles. The power wheelchair could be operated by a joystick located on the left or right to ensure that patients could use their preferred hand. In all cases, this was their ipsilesional hand. The power wheelchair (Invacare, Phoenix, AR, USA) measured 59 cm across at its widest point (lateral aspect of each rear wheel).

Wheelchair assessment course

The WAC was designed to provide a challenging assessment of navigation skills and involved negotiating 13 obstacles placed in specific and marked locations along a corridor. Obstacles were blocks of wood (25 cm × 3 cm × 3 cm) placed on their end and were easily visible. At the beginning and end of the WAC, obstacles formed "gates" with only a few centimetres clearance, which had to be negotiated by patients. Patients completed 10 trials each (except for TM who only completed 5 trials). On each trial, the number of collisions was counted and the side (ie, ipsilesional vs. contralesional) of collisions was noted. For more details of the WAC, please refer to supplementary materials.

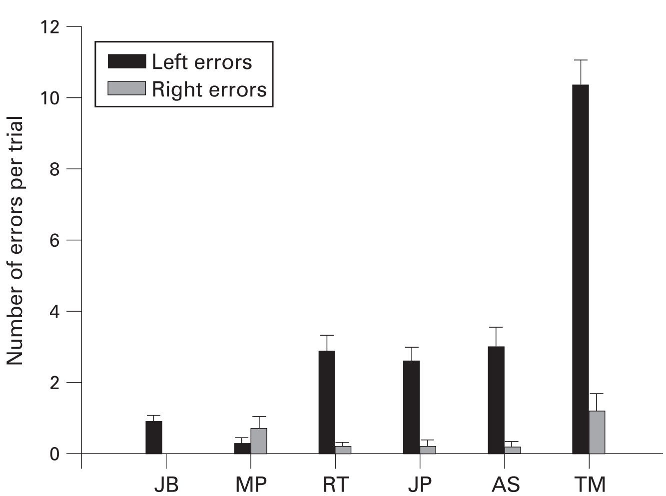

Figure 1 Number and side of errors for each individual patient on the wheelchair assessment course.

Doorway accuracy test

The DAT was designed to provide a finer-grained assessment of navigational performance. Here, patients were asked to navigate a central course though a series of openings. On each trial, patients approached the "gap" from a distance of 10 m perpendicular to the centre of the opening/gap. Each patient completed 24 trials. Three different-sized gaps (65 cm, 110 cm and 155 cm) were presented randomly across the trials. The position of obstacles was measured using 3D motion capture analysis (Qualisys, Gothenburg, Sweden) . On each trial, a marker that was located centrally on the chair provided an accurate measure of the chair's trajectory. An algorithm was written to calculate the point on the line between the two obstacles where the chair crossed, showing how accurate patients were in navigating a central course. Deviations to the contralesional side were given a negative value and deviations to the ipsilesional side were given a positive value to distinguish them in the analysis.

RESULTS AND DISCUSSION

Performance on the WAC confirmed the clinical observation of greater contralesional collisions (see fig 1). The mean number of errors for each trial shown by the six patients with neglect who completed the WAC was 3.75 (table 2). A strong asymmetrical bias characterised the errors with a mean of 3.35 for contralesional errors and only 0.4 for ipsilesional errors ($F (1,5) = 4.8$; $p<0.05$). Analysing the results for each individual (paired t-tests) revealed a reliable bias in all cases except MP (table 2).

The results on the WAC demonstrate the difficulties encountered by patients with neglect when navigating a power wheelchair. Results confirmed the clinical observation that patients with neglect tend to bump into objects primarily on their contralesional or "neglected" side. Our results also demonstrate a range in severity across the patients. In some cases (eg, JB), errors were relatively minimal, whereas in others (eg, TM), errors were almost maximal on some trials.

Table 2 Paired t-tests for individual patients on the wheelchair assessment course

JB	$t(9) = 5.01$; $p<0.005$
RT	$t(9) = 8.91$; $p<0.001$
MP	$t(9) = -1.0$; $p = 0.34$
TM	$t(4) = 10.7$; $p<0.001$
JP	$t(9) = 5.62$; $p<0.001$
AS	$t(9) = 4.73$; $p<0.005$

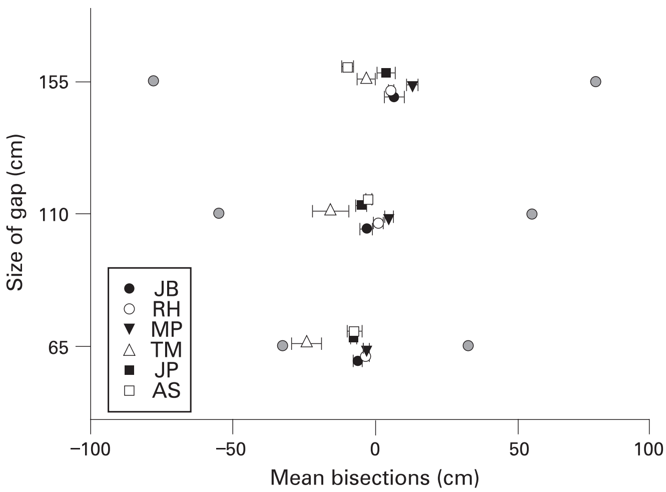

Figure 2 Deviations from midline shown for each individual on the doorway accuracy test. The grey-filled circles represent the "posts" between which the patients navigated. Ipsilesional errors have a positive value and contralesional errors have a negative value for consistency across patients.

The DAT was also completed by six patients. However, RT was unable to perform this assessment. A patient who had not completed the WAC (RH) completed the DAT along with the other 5 patients. Signed data from the DAT were initially subject to an analysis of variance (ANOVA), for which the factor was gap size (65 cm vs. 110 cm vs. 155 cm). This resulted in a significant "crossover" effect for the group ($F(2,10) = 6.48$; $p<0.05$). As can be seen in figure 2, patients tended to deviate ipsilesionally for the larger gap but, as the gap became smaller, errors became increasingly contralesional. In addition to the significant group effect found, all individual patients (except AS) demonstrated a significant "crossover" effect.

Further analysis of these data may provide some explanation for the crossover found. Subtracting the "distance from the contralesional object" from the "distance from the ipsilesional object" reveals the difference in the distances from each object. Resulting values are high for the small gap (17.3 cm), but become progressively smaller for the medium gap (6.8 cm) and negative for the large gap (−5.3 cm), indicating that the distance to the ipsilesional object remained relatively constant as the distance to the contralesional object changed markedly across the different gap sizes. This finding is also borne out in the standard deviations of these distances, which are far greater when measuring from the contralesional rather than the ipsilesional object (ipsilesional = 169.3 mm, contralesional = 282.3 mm, $t(5) = 3.5$; $p<0.05$). This relatively constant distance to the ipsilesional object, which persists across gap sizes, suggests that patients are disproportionately influenced by the ipsilesional object when steering a midline course. In a task such as wheelchair navigation, this behaviour is perhaps enhanced by the patients' concern for safety and their aim of avoiding collisions on the side to which they are attending. Such a bias is consistent with the competitive nature of stimuli in neglect, which is demonstrated through the associated problem of extinction[11] and with accounts that stress an attentional gradient with an ipsilesional bias.[12]

Across patients, the results on the DAT mimic results found on pen-and-paper line bisection tests that were previously demonstrated in patients with neglect.[5 6 13] The finding of crossover has fascinated neuropsychologists for many years,[14] but has previously only been discussed in terms of its theoretical relevance. Here, we see that the behaviour has important implications for the functional task of wheelchair navigation.

Another important implication of our study is the finding that some patients who did not show neglect on standard assessment, but only on more sensitive laboratory-based tests (AS, JB, RH), had marked difficulties on navigation tasks. This dissociation of performance on standard versus functional tests of neglect is rare in the literature,[15] but is of interest both in terms of its clinical relevance and our understanding of cognitive processes. Our data suggest that such dissociations, although rare in the literature, are perhaps relatively common in practice.

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REFERENCES

1. **Stone SP,** Wilson B, Wroot A, *et al*. The assessment of visuospatial neglect after acute stroke. *J Neurol Neurosurg Psychiatry* 1991;**54**:345–50.
2. **Buxbaum LJ,** Ferraro MK, Veramonti T, *et al*. Hemispatial neglect: Subtypes, neuroanatomy, and disability. *Neurology* 2004;**62**:749–56.
3. **Karnath H-O,** Milner AD, Vallar G. *The Cognitive and Neural Bases of Spatial Neglect*. Oxford: Oxford University Press, 2003.
4. **Webster JS,** Rapport LJ, Godlewski MC, *et al*. Effect of attentional bias to right space on wheelchair mobility. *J Clin Exp Neuropsychol* 1994;**16**:129–37.
5. **Mennemeier M,** Pierce CA, Chatterjee A, *et al*. Biases in attentional orientation and magnitude estimation explain crossover: neglect is a disorder of both. *J Cogn Neurosci* 2005;**17**:1194–211.
6. **McIntosh RD,** Schindler I, Birchall D, *et al*. Weights and measures: a new look at bisection behaviour in neglect. *Brain Res Cogn Brain Res* 2005;**25**:833–50.
7. **Savazzi S,** Posteraro L, Veronesi G, *et al*. Rightward and leftward bisection biases in spatial neglect: two sides of the same coin? *Brain* 2007;**130**:2070–84.
8. **Wilson B,** Cockburn J, Halligan P. Development of a behavioral test of visuospatial neglect. *Arch Phys Med Rehabil* 1987;**68**:98–102.
9. **Posner MI,** Inhoff AW, Friedrich FJ. Isolating attentional systems—a cognitive-anatomical analysis. *Psychobiology* 1987;**15**:107–21.
10. **Mesulam M.** Functional anatomy of attention and neglect: from neurons to networks. In: Karnath HO, Milner AD, Vallar G, eds. *The Cognitive and Neural Bases of Spatial Neglect*. Oxford: Oxford University Press, 2002:33–45.
11. **Driver J,** Vuilleumier P. Perceptual awareness and its loss in unilateral neglect and extinction. *Cognition* 2001;**79**:39–88.
12. **Kinsbourne M.** Mechanisms of neglect: Implications for Rehabilitation. *Neuropsycholog Rehabil* 1994;**4**:151–3.
13. **Halligan PW,** Marshall JC. How long is a piece of string? A study of line bisection in a case of visual neglect. *Cortex* 1988;**24**:321–8.
14. **Mesulam MM.** Spatial attention and neglect: parietal, frontal and cingulate contributions to the mental representation and attentional targeting of salient extrapersonal events. *Philos Trans R Soc Lond B Biol Sci* 1999;**354**:1325–46.
15. **Grossi D,** Lepore M, Napolitano A, *et al*. On selective left neglect during walking in a child. *Brain Cognition* 2001;**47**:539–44.