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The Recovery of Spatial Deficits in a Young Man with a Fronto-Parietal Infarct of the Right Hemisphere*

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This case study of an 18-year-old man who sustained an extensive right frontoparietal infarct as the result of an occlusion of the right internal carotid artery, documents the differential recovery of visuospatial neglect, body neglect, and deficits of visuospatial perception and spatial visualization. Left-right orientation and memory and verbal abilities were never impaired. Body neglect recovered first, followed by visuospatial neglect within twelve days of the stroke. Deficits of visuospatial perception and spatial visualization were apparent fifteen days following the stroke, but had recovered significantly at a six-month follow-up.

The recovery of nonverbal functions following brain damage is sparsely documented, especially when compared with the extensive literature on the treatment and recovery of the aphasias (Kertesz, 1979). Given that the debilitating effects of a language deficit are often more obvious than the problems caused by a spatial deficit, it is perhaps not surprising that so much research effort has gone into the understanding and treating of language deficits. However for many patients, spatial deficits such as hemineglect, topographical disorientation, or contructional apraxia can be very debilitating. For example, some studies have found that patients with left hemiplegia recover the use of their limbs more slowly than patients with right hemiplegia, and it has been suggested that this is a result of spatial-perceptual deficits and hemineglect suffered by the patients with right hemisphere damage (Cassvan, Ross, Dyer, & Zane, 1976; Knapp, 1957; Lawson, 1962). For people who rely heavily on spatial abilities in their work, a spatial disorder may be as debilitating as dyslexia is to most literate people.

While spatial functions are by no means as clearly lateralized as verbal functions, there is ample evidence that the right hemisphere plays a major role in many spatial abilities (see De Renzi, 1982, for review). Although patients with left hemispheric lesions do quite commonly suffer from spatial deficits such as constructional apraxia (Arena & Gainotti, 1978) and visual hemineglect (Albert, 1973; Ogden, 1985a, 1985b), the range and severity of spatial disorders suffered by patients with right-hemispheric lesions tends to be much greater (Faglioni, Scotti, & Spinnler, 1971; Gianotti, Messerli, & Tissot, 1972; Levine, Warach, Benowitz, & Calvanio, 1986; Mack & Levine, 1981). There is also some evidence that the spontaneous recovery time for left hemineglect (i.e., patients with right-hemispheric lesions) is longer than that for right hemineglect (Zarit & Kahn, 1974).

The following case study of a young man with an interest in architecture, documents the degree to which higher spatial functions can differentially recover without extensive specialist rehabilitation in a matter of months following a right-hemispheric infarct.

Case Report

History and Neurological Findings

R.G., an 18-year-old caucasian male university student, was seen at the Accident and Emergency Department following a motorbike accident. At the time of the accident he was wearing a crash helmet that covered his whole head. He was concussed for one to two minutes, and he had a minimal retrograde and anterograde amnesia of no more

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than a minute. Apart from a fracture of the right clavicle and a graze on the right side of his neck caused by the helmet strap, general and neurological examinations were normal. However, while he was waiting for X-ray, he experienced flashing lights in his left visual field accompanied by a drop of the left side of his face that resolved in a matter of minutes. He was sent home and he remained alert and appropriate for the next 24 hours until he experienced a further episode of flashing lights in his left visual field, this time lasting about 20 minutes. An hour after this he had a sudden onset of left facial and left arm weakness that steadily worsened over the next 30 minutes.

On urgent admission to Auckland Hospital R.G. was drowsy and confused, had developed a headache, and had vomited once. He had a marked weakness of the left face and left arm and a less marked weakness of the left leg. He demonstrated visual extinction on double simultaneous stimulation (DSS). He had an impairment of all forms of sensation over the left side of his body. Carotid angiography showed a complete occlusion of the right internal carotid artery approximately 2cm from its origin. The appearances were those of dissection of the right internal carotid artery with subsequent thrombotic occlusion. This was probably the result of bruising of the internal carotid artery by the strap of the crash helmet on impact. Computerized Tomography (CT) of his brain at this stage excluded a haemorrhage, but was suggestive of an early right parietal infarct. A second CT scan five days later showed an extensive infarct in the posterior frontal/anterior parietal region of the right hemisphere. The borders were well demarcated and there was a slight mass effect. He was treated conservatively with aspirin.

Immediately following his stroke, R.G. demonstrated a severe neglect of the left side of his body. For example, he seemed unable to move his left arm or leg, and believed they were completely paralysed. He depersonalized his left limbs and made comments such as 'It doesn't want to move'. He seemed unaware when his left limbs lay in awkward positions, and would not attempt to cover them even when they looked 'blue' with cold. He preferred people to stand on his right side and said he felt uncomfortable talking to people to his left.

His tendency to neglect the left side of his body was explained to him and his bed was pushed against the wall on his right side to encourage him to attend to people and objects on his left. He was also constantly reminded by staff and other patients to attend to his left limbs and try to use them. Over the next seven days his awareness of the left side of his body became almost normal, and he was able to move his left leg and walk with assistance.

At the time of his discharge, three weeks after his stroke, he could walk a short distance with the aid of a stick, but still had a weak arm and slight left facial droop. Six weeks after his stroke he could walk and hop on either leg normally, his facial weakness was trivial, and he was left with a slight spasticity and clumsiness of his left arm with some impairment of two-point discrimination and joint position sensation. Nine months after his stroke his only neurological problems were a slight loss of sensation in the tips of his left fingers and at the left edge of his mouth, and some clumsiness of rapid alternating movement in the left hand with a spastic catch and some increase in the tendon reflexes. He also had difficulty identifying objects by touch with his left hand. These signs had not resolved two years following his stroke.

Neuropsychological Assessments and Comments

R.G. was strongly right-handed, with a laterality quotient of 81.8 on the Edinburgh Handedness Inventory (Oldfield, 1971). If his school and university grades are taken as a guideline, his premorbid Intelligence Quotient (IQ) would probably fall within the 'Superior' range.

According to family members, one of whom was an architect, R.G. had since childhood shown a particular aptitude for tasks requiring spatial abilities (e.g., drawing, map reading, topographical orientation and memory). At the time of his accident he was 10 weeks into his second year at university taking first and second year undergraduate courses in the hope of qualifying for a place in a degree course in Architecture the following year. As

any spatial deficits resulting from his right-hemispheric infarct might seriously disrupt his career plans, it was decided to document his progress by assessing him neuropsychologically soon after his stroke and six months later. At this follow-up he was reassessed on those tests on which he had previously shown a deficit relative to his global IQ.

Tests of memory and general intelligence

Fifteen days after his stroke, on the Wechsler Memory Scale (Wechsler, 1945) he attained a Memory Quotient of 143, a score that placed him at the upper end of the 'Very Superior' range. On the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955), he demonstrated a difference of 25 points between his Verbal and Performance IQ. Such a pattern is consistent with right-hemispheric damage (Chase, Fedio, Foster, Brooks, Di Chiro, & Mansi, 1984; Lezak, 1983). At the six month follow-up he was given the Performance subtests and Arithmetic and Digit Span of the WAIS, and on all of these subtests he bettered his performance by two to four scaled points. His Performance IQ had increased by 18 points and the difference between his Verbal and Performance IQ had decreased by 11 points. His test scores can be found in Table 1.

Further tests of spatial function

Fifteen days after his stroke R.G. was also assessed for visual extinction, visual drawing neglect (see Ogden, 1985a, for a description of these tests), left-right orientation (Money's Road Map Test; Money, Alexander, & Walker, 1965), the two-dimensional mental rotation test from the Luria—Nebraska Neuropsychological Battery (Golden, Hammeke, & Purisch, 1980) and 10 problems of mental folding from the Space Relations test of the Differential Aptitude Tests (DAT; Bennett, Seashore, & Wesman, 1962). He demonstrated no visual extinction or neglect, and made no errors on Money's Road Map Test which he completed in the very fast time of 44 seconds. His scores and times were impaired on mental rotation (6/8 in 4 minutes), and on mental folding (6/10 in 45 minutes). At a six month follow-up he was given parallel versions of mental rotation and men-

Table 1: *R.G.'s scaled scores on the WAIS subtests fifteen days and six months following his stroke, and his Wechsler Memory Scale (WMS) scores fifteen days after his stroke.*

WAIS

Verbal Subtests	15 days	6 mths	Performance Subtests	15 days	6 mths
Information	14	—	Digit Symbol	10	12
Comprehension	19	—	Picture Completion	12	14
Arithmetic	12	15	Block Design	12	16
Similarities	15	—	Picture Arrangememt	9	11
Digit Span	11	15	Object Assembly	7	11
Vocabulary	13	—			
Verbal IQ	126	133	Performance IQ	101	119

WMS, Form 1.

Subtests	Raw Score 15 days post-stroke	Maximum Score	Population Age Mean	SD
Information	6	6	5.96	.02
Orientation	5	5	5.00	0.00
Mental Control	9	9	7.5	1.97
Digit Span Forward	7	8	7.04	1.22
Digit Span Back	5	7	5.26	1.13
Logical Memory	22	23	9.28	3.10
Visual Reproduction	13	14	11.0	2.73
Associate Learning	17.5	21	15.72	2.81
Memory Quotient	143		102.9	5.46

tal folding tests in order to assess any improvement. His performance at this assessment was flawless and exceptionally fast (26 seconds on mental rotation and 3.5 minutes on mental folding).

Outcome

On leaving hospital three weeks after his stroke, apart from attending physiotherapy clinic four times in total over the following four weeks, R.G. had no further rehabilitation. He attended the occasional lecture at the university before deciding to drop five of the eight courses he had been taking before his accident. At the end of the university year (five months after his accident) he sat his final exams in the three courses he had continued with and passed them all. He took a job as a dish washer in a restaurant for the summer vacation, and also prepared a folio of sketches that was one of the requirements for entry into architecture school. On the basis of his grades and the standard of his folio of sketches, he gained a place in Architecture. Two years after his stroke he was still studying for his Architecture degree, but was experiencing difficulty with advanced courses that involved visualizing complex buildings in three dimensions.

Discussion

The young man described in this case report is of interest primarily because of the rapid improvement in his spatial abilities after sustaining an extensive right frontal-parietal infarct. His acceptance into Architecture School under very competitive circumstances, partly on the basis of a series of sketches he had drawn six months after his stroke, is practical evidence of the extent of his recovery, although it is unlikely that his spatial abilities recovered to premorbid levels.

When his memory and verbal functions were assessed fifteen days after his stroke, his scores were all within the 'Very Superior' range. This indicated that R.G. was not by this stage suffering from significant problems of impaired retention, concentration, attention and fatigability that are often characteristic of an acute brain condition (Lezak, 1983). That is, any diffuse or generalized symptoms that may have been present immediately following the stroke (possibly as a result of oedema) appear to have resolved.

While the timed nature of the WAIS Performance subtests may in part have accounted for R.G.'s significantly lowered scores on these visuospatial tests, his qualitative performance suggested that his difficulties were not primarily the result of motor slowing or problems of hand-eye coordination. For example, he had no difficulty physically manipulating the blocks when carrying out the Block Design subtest of the WAIS, and he was completely unable to work out the tenth Block Design problem or the 'elephant' problem of 'Object Assembly' even when given unlimited time. Although he had a marked left-sided neglect of his body and a mild left-sided visual neglect immediately following his stroke, these had resolved by the time he was assessed on the WAIS, and therefore hemineglect is unlikely to have contributed significantly to his lowered scores.

Consideration must be given to the possibility that a practice effect may have contributed to R.G.'s performance when he was retested on the WAIS six months after his first assessment. Matarazzo, Carmody, & Jacobs (1980) reviewed 11 studies reporting the test-retest stability of the WAIS and concluded that a mean practice effect of +5 IQ points is to be expected on retesting with the WAIS, but point out that a few individuals increase their IQ by up to 14 IQ points without any clinical intervention. Shatz (1981) showed that with a single retesting on the WAIS, brain-damaged subjects demonstrated significantly smaller increases than normal subjects, and concluded that in general a 4 to 5 point change is clinically significant 66% of the time, and an 8 to 10 point IQ change probably defines the 95% confidence interval for significant individual change. Therefore the 18 point increase in R.G.'s Performance IQ over six months is highly likely to reflect a real and impressive improvement in R.G.'s visuospatial perceptual and cognitive functions. The fact that R.G.improved significantly over six months on mental rotation and mental folding, both tasks requiring mental imagery and spatial cognition, but without a motor component, is further evidence that R.G. recovered his ability to think spatially to a significant degree.

R.G. was favoured by a number of factors

that have been found to generally influence recovery after brain damage. For example, he was well educated (Finlayson, Johnson, & Reitan, 1977), had been a stable and well-adjusted teenager prior to his stroke (Gloning, Gloning, & Hoff, 1968; Walker & Jablon, 1959), and seemed highly motivated to recover after his stroke (Henley, Pettit, Todd-Pokropek, & Tupper, 1985). His relatively young age may have been a positive factor, although there is little evidence to support the notion that age influences recovery of function except in children younger than about 13 years, and in adults older than about 45 years (Lezak, 1983). While these general factors might provide a favourable milieu for recovery, they do not explain the mechanisms of recovery. General explanations for the recovery of function include the resolution of oedema, an increased blood flow reinstating function in neurons that were temporarily dysfunctional but not dead, and the establishment or use of new or rarely used functional pathways in the undamaged regions of the brain.

Specifically, R.G. showed no deficit on left-right orientation, he recovered rapidly from mild visuospatial neglect and moderate body neglect, and he demonstrated a more gradual improvement on the Performance subtests of the WAIS and on tasks involving mental imagery (mental rotation and mental folding).

R.G.'s excellent performance following his stroke on Money's Road Map Test suggests that left-right orientation is not subserved by the same anatomical area that subserves mental rotation and mental folding. Indeed, left-right disorientation is usually associated with left-sided brain damage (Ogden, 1985c; Rosati, De Bastiani, & Pinna, 1979).

While R.G. did not undergo intensive rehabilitation, it is possible that the recovery of his neglect was accelerated by the early explanations given to him of the neglect phenomena, and the constant encouragement he received from staff and patients to attend to his left side. Given his intact verbal abilities, he may also have made use of verbal mediation to remind himself to attend to his left side, and to mediate tasks involving spatial cognition.

A large research study which looked at the anatomical correlates of severity and recovery of left visuospatial neglect (Levine et al., 1986) found no correlation between degree of recovery of neglect over 20 weeks and age, but found that recovery of neglect was positively correlated with the size of the right-hemispheric infarct, and the degree of pre-stroke cerebral atrophy. Given R.G.'s youth, the fact that his stroke was the result of an accident rather than cerebrovascular disease, and his superior verbal and memory abilities when assessed soon after his stroke, it seems almost certain that he would have no significant atrophy of either his left hemisphere or the non-infarcted right areas of his right hemisphere. No atrophy was seen on CT scan. Using Levine et al.'s criteria, R.G.'s infarct was of medium size.

Levine et al. suggested that the amount of functional brain tissue in both hemispheres is critical in determining the recovery of neglect after right-hemispheric stroke. Ogden (1987) proposed that visuospatial neglect may in part be a consequence of the general physiological and/or functional disorganisation that occurs in the hemisphere immediately following a lesion to one part of it. This general disturbance might be sufficient to degrade the image of the opposite hemispace. When the lesion is a non-progressive infarct and the rest of the brain is healthy, this widespread disturbance is transitory, and recovery of neglect occurs as the healthy brain restabilizes around the lesion. While such theories provide possible explanations for R.G.'s rapid and complete recovery from neglect, his more gradual recovery on tasks involving mental imagery (mental rotation and mental folding) may be explained by evidence that both the left hemisphere (Erlichman & Barrett, 1983; Farah, 1984; Farah, Gazzaniga, Holtzman, & Kosslyn, 1985; Ogden 1985b, 1987) and the right (Bisiach, Capitani, Luzzati, & Perani, 1981; Bisiach, Luzzati, & Perani, 1979; Ogden, 1985b; Ratcliffe, 1979) are implicated in tasks involving mental imagery. If both hemispheres are potential mediators of imagery processes, possibly with the right hemisphere taking a more dominant role in visuospatial imagery in the normal brain, then perhaps R.G.'s improvement over time on these tasks could be the result of the left hemisphere taking over these functions to a greater degree.

In R.G.'s case, while substantial recovery

has occurred, his abilities may not have recovered to premorbid levels, given that his Performance IQ remains lower than his Verbal IQ, and that according to his tutor in architecture, he appears to have a specific difficulty with advanced courses involving the ability to visualise buildings in three dimensions. R.G.'s case underlines the need to view recovery of function in the context of the individual's premorbid abilities and lifestyle. While R.G.'s spatial abilities recovered to levels most people would be well satisfied with, he may be permanently disadvantaged because of the impairment of a specialised spatial ability that most people are probably never skilled at.

To summarize, this case study documents the differential rate of recovery of left body neglect, left visuospatial neglect, and impairment of visuospatial perception and spatial cognition and imagery in a young man with a right frontoparietal infarct. The patient demonstrated little or no impairment on memory tests, verbal subtests of the WAIS, or on left-right orientation. While examples of similar cases may well be quite common in a clinical setting, there are few reports documenting the impairment and recovery of different spatial functions.

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