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Neurorehabilitation Following Right Thalamic Infarct: Effects of Cognitive Retraining on Functional Performance*

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ABSTRACT

We treated the cognitive impairments of a 69-year-old male, that persisted 7 months after an infarction in the distribution of the right posterior cerebral artery. The infarct produced a 20% reduction in right cerebral blood flow, established by positron emission tomography (PET). Neuropsychological status was characterized by marked hemivisuospatial inattention, visuoperceptual and perceptuomotor dysfunction, and impaired visual memory. A multiple-baselines across behaviors design was utilized to assess effects of specific interventions on targeted cognitive functions. We found significant improvement in attention to left hemispace in response to directed interventions. Considerable gains were also realized in perceptuomotor abilities, mobility, and activities of daily living. Results indicated process-specific effects of strategic cognitive interventions, initiated 7 months postonset.

Neurorehabilitation services have proliferated over the past 20 years and the interdisciplinary team approach to rehabilitation has become the standard model of service delivery. However, when patients make functional gains, it is unclear just how improvement emerged. Whether or not the outcome could have been facilitated by any physical or behavioral intervention, spurred by spontaneous recovery remains unanswered (Dobkin, 1989). Cognitive retraining has more recently become a major component of rehabilitation following neurological insult. Here too, efficacy studies are generally unavailable and it is unclear whether

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or not patients benefit from cognitive rehabilitation, particularly with regard to significant changes in quality of living (Berrol, 1990; Levin, 1990).

The published studies in the neurology, neuropsychology, and rehabilitation literature that describe the effectiveness of a specific cognitive intervention or cognitive rehabilitation program (e.g., Ben-Yishay, Silver, Piasetsky, & Rattok, 1987; Hanlon, Brown, & Gerstman, 1990; Prigatano et al., 1984; Schacter, Rich, & Stamp, 1985; Sparks & Holland, 1976; Weinberg et al., 1977) seem underrepresented, given the time spent in a proliferating number of programs. Randomized, controlled trials of a specific treatment are nearly nonexistent. In addition to ethical concerns about withholding a treatment program, confounding variables that might preclude such studies include the heterogeneity of patients and spontaneous recovery.

Single-case designs, which can include multiple-baselines and alternating treatment, are clinically well established and accepted in, for example, behavioral modification studies (Wood, 1987). As a result of growing frustration with group studies in cognitive rehabilitation and advances in the methodological sophistication of single-case experimental designs (Barlow & Hersen, 1984; Kazdin, 1982), N-of-1 designs have recently met with increased acceptability and popularity in neuropsychological rehabilitation (e.g., Gianutsos & Gianutsos, 1979; Sohlberg & Mateer, 1987; Wilson, 1987).

The neurological and neuropsychological sequelae associated with right-hemisphere lesions are well documented. These include impairments in left spatial attention (Costa, Vaughan, Horwitz, & Ritter, 1969; Heilman, Watson, & Valenstein, 1985; Mesulam, 1981; Weintraub & Mesulam, 1987), visuoperception and perceptuomotor function (Benton, 1985; DeRenzi, 1982; McFie & Zangwill, 1960), visual memory (Milner, 1968; Speedie & Heilman 1983), left hemiplegia (Brodal, 1973), and left-sided unimodal or multimodal sensory loss (Hier, Mondlock, & Caplan, 1983a). They may, singularly or collectively, produce severe functional disability.

Recovery of function following a right-hemisphere lesion has also been well documented for cognitive impairments, sensory loss, and motoric dysfunction (Hier, Mondlock, & Caplan, 1983b), as well as for affective disorders (Egelko et al., 1989). Hier et al. (1983b) found that spontaneous recovery from unilateral spatial neglect and visuoconstructional impairment steadily progressed during the first 5 months postonset, followed by a plateau with negligible probability of further recovery.

The time required for maximal recovery from neuropsychological impairments following neurological insult, and particularly clinical estimations of duration of recovery, remains a controversial issue in neurorehabilitation. Recovery of language and motor functions in aphasic patients following left hemisphere lesions has received considerable attention (e.g., Basso, Capitani, Della Sala, Laiacina, & Spinnler, 1987; Kertesz & McCabe, 1977; Lendrem & Lincoln, 1985; Sarno & Levita, 1971). Kertesz (1985) has noted that, although recovery from aphasia may continue during the first year post-stroke, the greatest amount of recovery

occurs during the first three months and "after six months, the rate of recovery significantly drops" (p. 492). This appears to be essentially the same pattern for impairments commonly associated with right hemisphere lesions (Hier et al., 1983b).

We present a single-case design for treatment of cognitive impairments secondary to the patient's right cerebral infarct. Cognitive rehabilitation was initiated 7 months postonset, thereby minimizing the confounding influence of spontaneous recovery on the effect of cognitive retraining. The interventions were administered by all members of an interdisciplinary rehabilitation team as part of discipline-specific tasks and objectives. In addition to determining the effect of process-specific cognitive interventions on neuropsychological test performance, the influence of cognitive retraining on functional performance in specified areas of physical functioning and activities of daily living (ADL) was examined pre and posttreatment.

METHOD

Subject

The subject, a 69-year-old male, was bilingual and functionally right-handed, although he was reported to be a natural left-hander who was forced to develop a right-handed preference as a child. Six months after onset of his stroke, an MRI revealed an infarction in the distribution of the right posterior cerebral artery, involving the right thalamus, posterior limb of the internal capsule, and mesial occipital lobe (Figure 1). Eight months after onset, positron emission tomography (PET) revealed a 20% decrease in right cerebral blood flow, relative to the left hemisphere, on an Oxygen-15 cerebral blood flow study (Figure 2).

Previous treatment had not included cognitive rehabilitation therapy and had focused exclusively on physical rehabilitation, with an emphasis on right-sided compensation for left-sided motoric dysfunction. He had achieved ambulation with moderate assistance. At approximately 7 months postonset, he was transferred to UCLA Medical Center and began a 3-month course of daily neurorehabilitation; this included physical, occupational, and speech/language therapy, and neuropsychological services.

The patient manifested a left hemiparesis with mostly patterned strength graded 3/5, left hemianesthesia with absent proprioception, and a left homonymous hemianopsia. Neuropsychological findings included marked left spatial inattention, impaired visuo-perceptual and perceptuomotor functions, (e.g., WAIS- R Performance IQ = 68), and defective visual-nonverbal memory. Speech/language assessment of reading on the Reading Comprehension Battery For Aphasia (LaPointe & Horner, 1979) revealed deficient reading accuracy and comprehension, primarily due to neglect of left hemispace in visual scanning.

Physical and occupational therapy evaluations utilized a standard 5-point clinical rating scale, based on the amount (%) of assistance required in functional performance. Functional status was scored as follows: 5 = Dependent (76-100% assistance), 4 = Maximal assist (51-75% assistance), 3 = Moderate assist (26- 50% assistance), 2 = Minimal assist (1-25% assistance), 1 = Independent (0% assistance). His unsteady asymmetrical gait required moderate assistance for ambulation. Standing balance and transfers to and from a wheelchair also required moderate assistance. Occupational therapy evaluation of activities of daily living (ADL) revealed the following: dressing, bathing, and toileting required maximal assistance, and grooming and feeding required moderate assistance.

Examples of the effect of hemivisuospatial inattention and neglect of the hemiparetic side on functional performance included the following: he would run into furniture and doorways with the left side of his wheelchair; when unsupervised, his left arm would hang over the left side of his bed or wheelchair; in assisted but unguided ambulation, he demonstrated a 3-foot deviation to the right per 30 feet of walking distance; he demonstrated variable neglect of the left side in grooming and dressing; when eating, he was unaware of food or utensils placed beyond 8 inches to the left of midline.

Procedure

A multiple-baselines across behaviors design was implemented to assess the effect of structured interventions on specific cognitive functions across consecutive treatment intervals (Barlow & Hersen, 1984). This required an initial baseline evaluation (Week 1), followed by the first treatment interval (Weeks 2-6), the focus of which was on a previously selected deficit. After completion of the first treatment interval, a second baseline evaluation was conducted (Week 7). Following this, the second treatment interval was completed (Weeks 8-12), the focus of which was on another deficit. A third baseline evaluation was conducted at Week 13.

Four cognitive functions (hemivisuospatial attention, visuoperceptual processing, visuoconstruction, and visual-nonverbal memory) were established as dependent variables and were assessed at Weeks 1, 7, and 13. The four functions were operationalized as follows: Hemivisuospatial attention was assessed on the four forms of the Cancellation Test (Weintraub & Mesulam, 1985); Visuoperceptual capacity was assessed on the Visual Form Discrimination Test (Benton, Hamsher, Varney, & Spreen, 1983) and the Hooper Visual Organization Test (Hooper, 1958); Visuoconstructional ability was assessed on the Revised Visual Retention Test (Copy Administration) (Benton, 1974) and the Complex Figure Test (Copy Administration) (Rey, 1941); Visual Memory was assessed on the Revised Visual Retention Test (immediate recall) (Benton, 1974) and the Complex Figure Test (immediate recall) (Rey, 1941). The influence of cognitive interventions on functional performance in mobility and activities of daily living (ADL) was also monitored in nine specified areas: functional use of the left arm and hand, ambulation, transfers, postural control, dressing, bathing, toileting, grooming, and feeding.

The focus of the first 5-week treatment interval was conditioning of responsive and spontaneous visual scanning of left hemispace. A multisensory cueing strategy (i.e., visual, auditory, proprioceptive, and tactile) involving explicit left-sided cueing was employed by all members of the neurorehabilitation treatment team. Cues included auditory-verbal commands and auditory-nonverbal stimuli to direct and orient the subject to left hemispace, visual cues (such as salient peripheral left visual field stimuli and gestures redirecting the subject to left-sided scanning) as well as therapeutic positioning, placement, and touching of the left upper and lower limbs.

These interventions were progressively refined according to the saturation cueing technique (Diller & Gordon, 1981). The saturation cueing technique involves the systematic reduction in cues required for successful task completion. For example, once the subject began to search spontaneously for and locate the left visual field anchor (i.e., left peripheral visual stimulus), verbal commands to initiate left-sided scanning were progressively withdrawn. Similarly, once he began to use his left arm spontaneously in a stabilizing or supportive manner in paper-and-pencil and ADL tasks, strategic placement and tactile stimulation of the limb were progressively reduced.

We employed paper-and-pencil tasks, such as copying sentences and paragraphs and reading newspaper articles and other written materials; environmental visual search tasks, involving counting and identification of specified stimuli (e.g., money, people, windows, buildings, etc.); physical activities utilizing a mirror for visual feedback; and functional engagement of the left upper extremity (LUE) in ADL tasks to increase left-sided awareness/attention. A comprehensive and detailed description of the therapeutic tasks is available

upon request from the authors (also see Diller & Gordon, 1981; Weinberg et al., 1977).

In Week 7, a second cognitive treatment interval was initiated. This focused on visuospatial analysis and perceptuomotor integration. Treatment was directed toward the acquisition and utilization of a systematic approach to detailed visual analysis, requiring verbal elaboration and description of visual elements and spatial relations. This approach involved training in sequential, unidirectional visual analysis/synthesis incorporating verbal mediation. We used single and multiple-element configurations, including drawings, geometric forms, objects, routes, floor plans, and relatively complex scenes depicting social situations. For example, the subject was required to provide detailed verbal descriptions of the visuospatial attributes of the objects, people, and other environmental stimuli that he confronted during therapy sessions. This approach emphasized active and independent incorporation of the hemiparetic limb, but did not involve explicit cueing directed toward scanning of the left visual field. Following the second treatment interval, the third baseline evaluation was completed (Week 13).

Statistical Analysis

The use of statistics in single-case studies is a controversial issue (Wilson, 1987). The conventional method of data analysis in single-case designs is visual inspection of graphic display (Kazdin, 1984). Due to the fact that there is no inter-subject variability, generalization from single-case studies is limited. However, since the essential issue in single-case designs involves the observation of processes rather than static relationships, replication is crucial to the determination of the generalizability of effects (Yule & Hemsley, 1977). As a result, statistical effects in single-case studies address the variability of replication rather than intersubject variability. Statistical analysis in intrasubject designs is generally

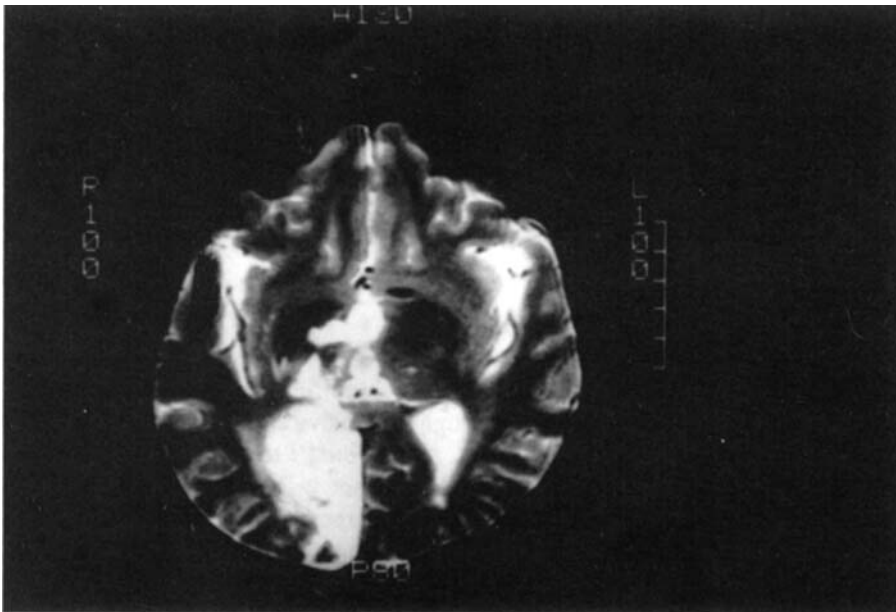


Fig. 1. MRI completed 6 months post-onset, revealing an infarction in the distribution of the right posterior cerebral artery.

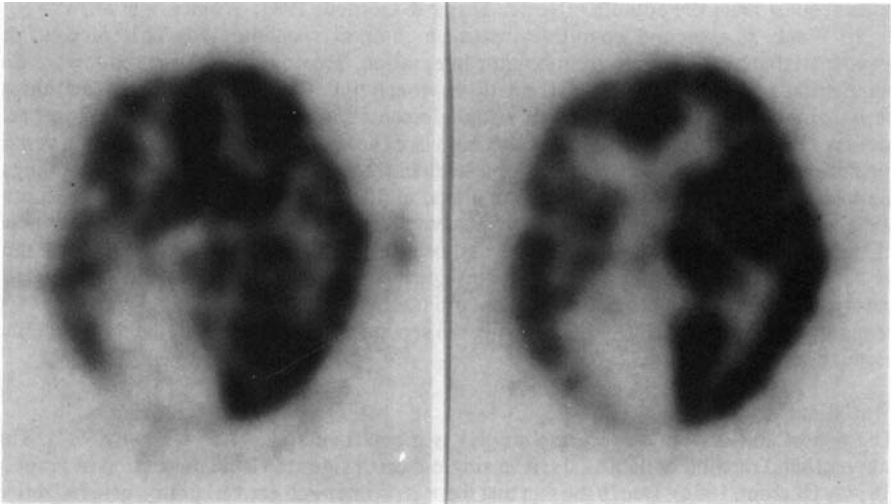


Fig. 2. Positron Emission Tomography (Oxygen-15 Study), revealing a 20% reduction in right cerebral blood flow.

used to provide further support for treatment effects evident on graphic display (e.g., Gentile, Roden, & Klein, 1972; Epstein, Herson, & Hemphill, 1974; Wood, 1987).

Following Gentile et al. (1972), the degree of change in the two target functions (i.e., hemivisuospatial attention and visuoperceptual processing) was assessed by repeated measures analysis of variance. The indirect effect of the targeted treatments on visuoperceptual ability and visual-nonverbal memory was assessed in the same manner. Following the repeated measures ANOVA, protected *t* tests were conducted to determine the specificity of effect. The influence of cognitive rehabilitation on functional performance in the two domains of physical/motoric function and activities of daily living was examined by visual inspection of graphic display.

RESULTS

On a repeated measures ANOVA, we found a significant increase in compensation for left visuospatial inattention through responsive and spontaneous scanning of left hemisphere ($F = 77.4, p < .001$). A protected *t* test comparison between Baseline 1 and Baseline 2 revealed a significant increase in attention to left hemisphere ($t = 18.34, p < .001$) as a result of directed therapeutic intervention, involving explicit multisensory cueing. Additionally, a *t* test comparison between Baseline 1 and Baseline 3 was also significant, ($t = 8.1, p < .01$), reflecting maintenance of the increased tendency for attending to left hemisphere, despite withdrawal of explicit cueing for left visual field scanning and a shift to another treatment. Figure 3 represents the degree of change in four cognitive functions

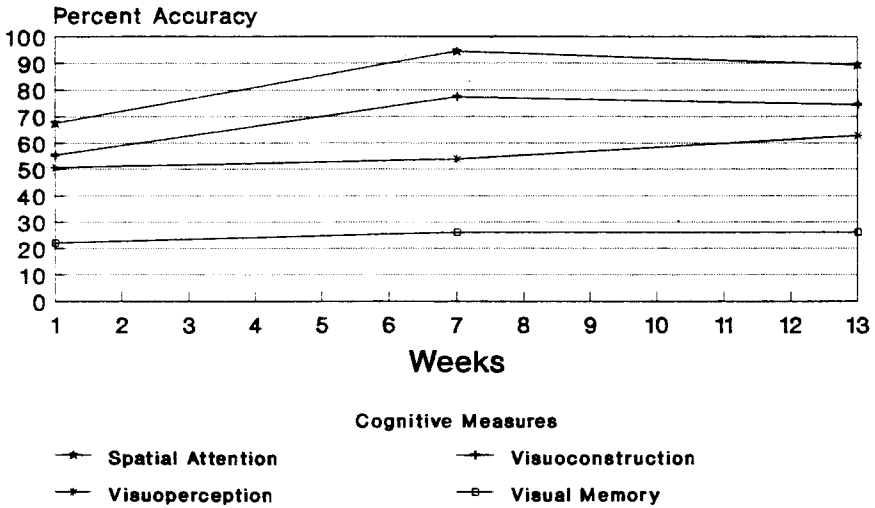


Fig. 3. Changes in selected functions resulting from cognitive rehabilitation (three neuropsychological baselines)

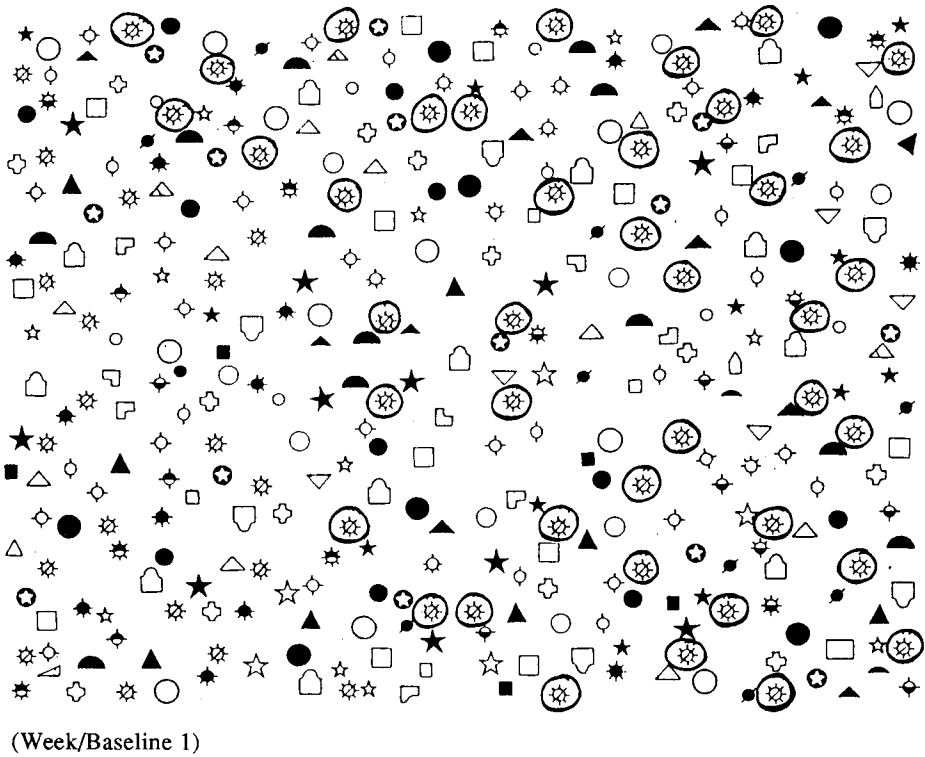
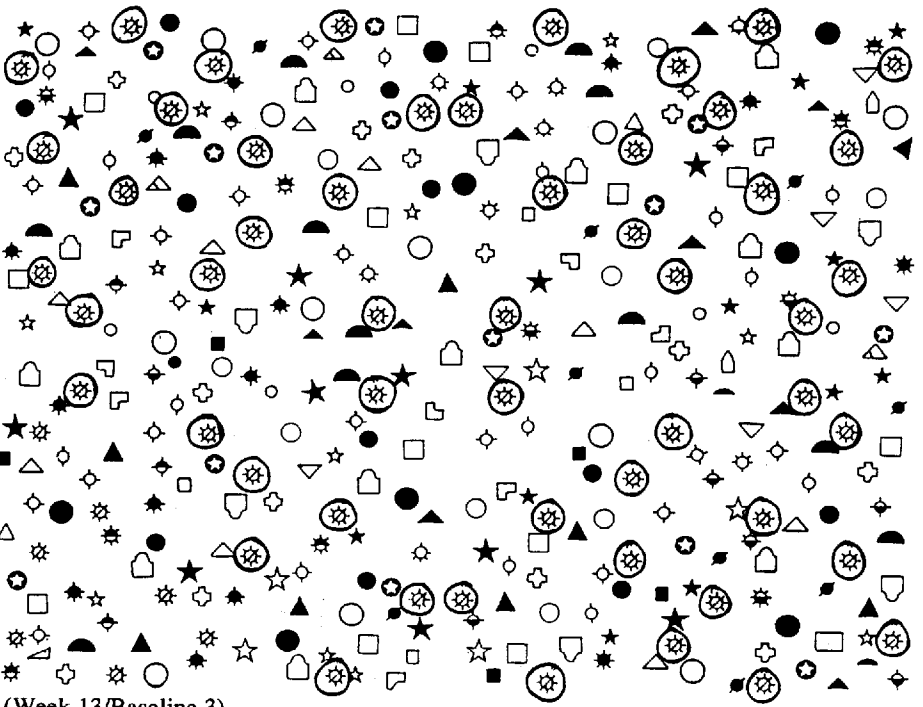
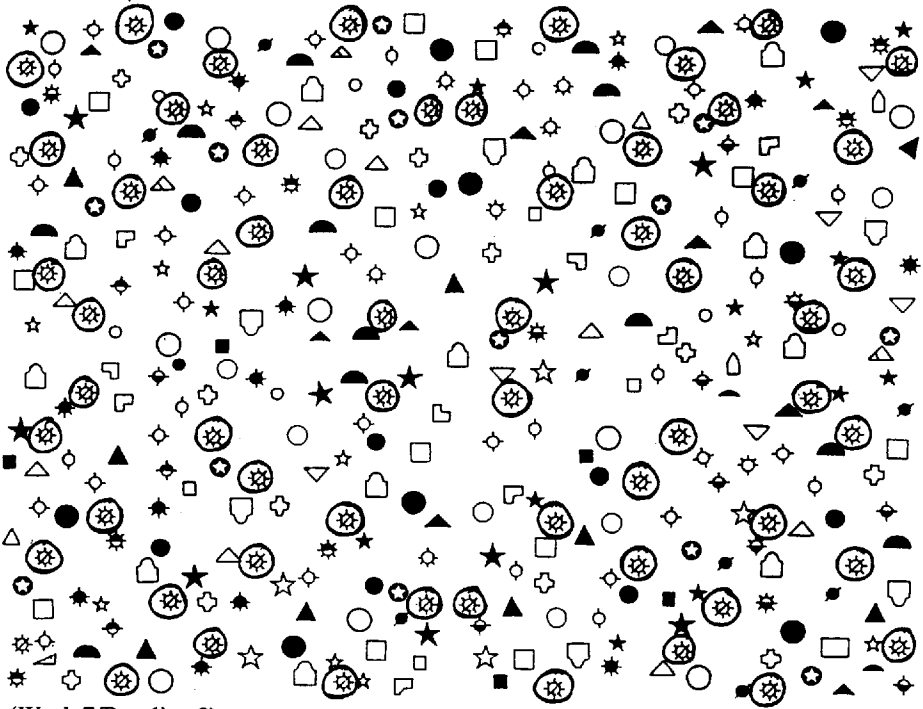


Fig. 4. Performance on one of the four forms of the Cancellation Test (Weintraub & Mesulam, 1985), from each of the three baseline evaluations (i.e., Weeks 1, 7, and 13).



across three baseline evaluations. Figure 4 is a sample performance on one of the four forms of the Cancellation Test from each of the three baseline evaluations.

Although the functional improvement noted in visuo-perceptual processing is evident on visual inspection of the graphic display (Figure 3), this increase was not statistically significant ($F = 4.6, p = .18$). However, notable improvements were revealed in both PIQ and reading performance, as assessed on the RCBA, from admission (Baseline 1) to discharge (Baseline 3). It should be noted that a practice effect may have contributed to the increases in PIQ and RCBA scores. However, given the defective level of performance on both of these measures at Baseline 1, it seems unlikely that a single exposure to these measures would have significantly increased performance 3 months later. Table 1 presents the test scores from the measures completed at each of the three neuropsychological baseline evaluations. Table 2 presents the WAIS-R Performance Scale scores and the RCBA subtests scores.

Considerable improvement was noted in visuo-constructional ability and this

Table 1. Test Performance from Three Neuropsychological Baseline Evaluations.

Test	Baseline 1 Pretreatment Week 1	Baseline 2 Treatment #1 Week 7	Baseline 3 Treatment #2 Week 13
Cancellation Test			
Form 1	41/60 (68%)	57/60 (95%)	53/60 (88%)
Form 2	43/60 (72%)	57/60 (95%)	54/60 (90%)
Form 3	41/60 (68%)	59/60 (98%)	53/60 (88%)
Form 4	37/60 (62%)	54/60 (90%)	55/60 (92%)
VRT(Copy)			
Score	4/10 (40%)	7/10 (70%)	7/10 (70%)
Errors	10	3	5
Rey (Copy)	25.5/36 (71%)	30.5/36 (85%)	28.5/36 (79%)
VRT (Recall)			
Score	2/10 (20%)	3/10 (30%)	3/10 (30%)
Errors	15	9	9
Rey (Recall)	8.5/36 (24%)	8/36 (22%)	8/36 (22%)
VFDT	25/32 (78%)	27/32 (84%)	28/32 (88%)
HVOT	7/30 (23%)	7/30 (23%)	11.5/30 (38%)

Note. Tests have been abbreviated as follows: VRT = Visual Retention Test, Rey = Rey Complex Figure, VFDT = Visual Form Discrimination Test, HVOT = Hooper Visual Organization Test.

Table 2. WAIS-R Performance Scores and Reading Comprehension Battery (RCBA) Scores at Pre (Baseline 1) and Post-treatment (Baseline 3).

Test	Pre-treatment (Baseline 1) 7 Months Poststroke	Post-treatment (Baseline 3) 10 Months Poststroke
PIQ:	68	78
(Age-Corrected Subtest Scores)		
Picture Completion	4	5
Picture Arrangement	4	7
Block Design	7	9
Object Assembly	1	4
Digit Symbol	4	8
RCBA Overall Score:	45	83
Word-Visual	7	10
Word-Auditory	8	10
Word-Semantic	8	8
Functional Reading	3	7
Synonyms	9	10
Sentence-Picture	7	6
Paragraph-Picture	3	8
Paragraph-Factual	0	9
Paragraph-Inferential	0	8
Morpho-Syntax	0	7

increase in accuracy of copy drawing approximated the trend which characterized the change in hemivisuospatial attention (See Figure 3). As a result, we believe that the improvement in visuoconstructional performance was secondary to the increased tendency for left visuospatial attention. However, this increase in accuracy of copy drawing did not reach commonly accepted levels of statistical significance ($F = 4.5, p = .18$). Finally, no notable indirect change was revealed in visual-nonverbal memory capacity as a result of interventions directed toward hemivisuospatial attention and visuo-perceptual processing.

Functional capacity in the two domains of physical function and activities of daily living (ADL) was evaluated on the previously described 5-point scale. This scale was based on the percentage of assistance required for task completion upon admission (Baseline 1) and at time of discharge (Baseline 3). These ratings were completed according to standard procedure in physical and occupational therapy assessments of functional performance. In an attempt to control for rater bias, these ratings were completed independently by three different therapists, both upon admission and at discharge; mean ratings in each of the nine areas of functional performance were computed therefrom.

In the assessment of physical functioning, these ratings were based on the following: initiation of movement, extent of volitional movement, support/assistance required to achieve and maintain standing balance, support/assistance required to transfer from wheelchair to bed and wheelchair to toilet, support/assistance required for ambulation across a flat surface and up/down stairs. Changes in the four subcomponents of physical function, including functional use of the hemiparetic limb (LUE), ambulation, transfers, and postural control are displayed in Figure 5. Although the patient demonstrated modest improvement in ambulation, transfers, and postural control, functional use of the hemiparetic LUE increased considerably. This increase in LUE function was presumably due to the treatment focus on left-sided awareness/attention and conditioning in the incorporation of the LUE in functional tasks.

Changes in ADL function were more pronounced, relative to improvements in physical/motoric function. Ratings completed by the occupational therapy staff at admission (Baseline 1) and discharge (Baseline 3) revealed notable improvement in all five subcomponents of ADL: dressing, bathing, toileting, grooming, and feeding. In the assessment of performance in ADL these ratings were based on the following: task initiation, task set-up requirements, sequencing, perseverance, and degree of physical assistance required. Changes in ADL status at pre- and post-treatment are presented in Figure 6. Apparently, this improvement in overall ADL status was due to a number of factors, including increased physical functions (particularly transfers and use of the hemiparetic limb), increased attention to left hemisphere, and increased capacity for perceptuomotor integration.

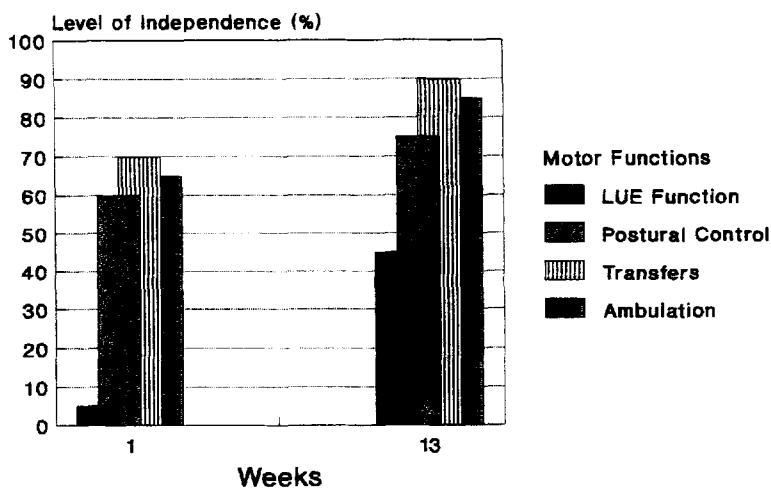


Fig. 5. Changes in physical function resulting from neurorehabilitation (based on 5-point rating scale).

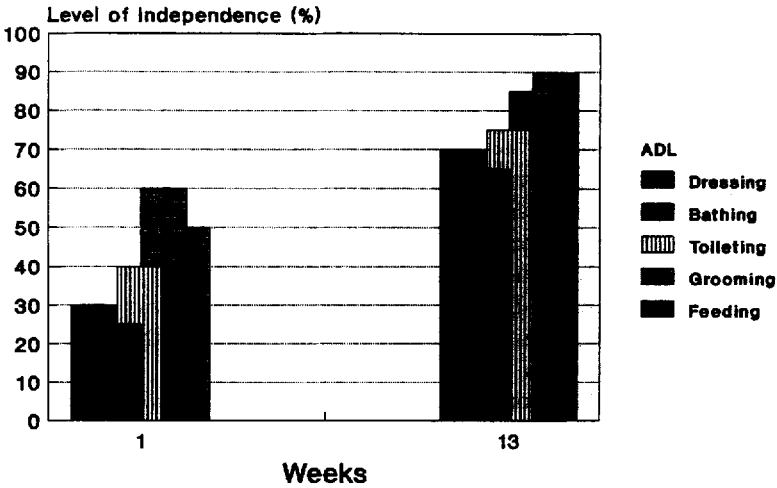


Fig. 6. Changes in ADL function resulting from neurorehabilitation (based on 5-point rating scale).

DISCUSSION

The purpose of this study was to determine the effect of process-specific cognitive interventions on cognitive-behavioral performance and to assess the impact of cognitive retraining on functionally oriented tasks. The subject had received extensive physical rehabilitation throughout the first 6 months poststroke, but remained markedly disabled due to both physical and cognitive dysfunction. He was probably beyond the stage of spontaneous recovery from cognitive deficits (Hier et al., 1983b), although subtle changes due to ongoing recovery could not be ruled out. Nevertheless, since he remained highly motivated to continue his rehabilitation and did not manifest a mood disorder, he was an ideal candidate for cognitive rehabilitation.

The findings provide support for the contention that process-specific effects of cognitive intervention may be achieved through strategic interdisciplinary treatment paradigms, and that a cognitive emphasis in neurorehabilitation may have a positive influence on functional performance. Furthermore, such effects may be achieved when treatment is initiated following plateau in the spontaneous recovery process (i.e., beyond 6 months postonset) (Hier et al., 1983b).

The finding of a significant increase in compensation for hemivisuospatial inattention in response to structured interventions aimed at conditioning of scanning of left visual space provides support for earlier findings on the effect of this technique (Weinberg et al., 1977). This finding is also extended to the post-recovery stage. That maintenance of this compensatory tendency was demon-

strated following withdrawal of explicit cueing seems to strengthen the inference regarding the effect of the intervention. Although maintenance of increased visual attention to left hemispace was demonstrated, it is evident on visual inspection of the graphic display that, relative to Baseline 2, hemivisuospatial attention at Baseline 3 was slightly decreased. The indirect effect of increased compensation for left spatial inattention on visuoconstructional ability was an interesting finding, but was not terribly surprising, given the interrelatedness of the two functions.

Although the effect of the second treatment focus (i.e., training in a sequential approach to visuospatial analysis involving extensive verbal mediation) was statistically insignificant, improvement was noted in both the psychometric and functional spheres. No indirect effect on visual memory function was expected in response to either treatment focus.

Although the findings discussed above are encouraging, it is equally important to consider the confounding influences that may have contributed in some part to the observed effects. As previously mentioned, it is possible, despite the fact that the patient had probably experienced maximal benefit from the spontaneous recovery process during the first 6 months postonset, that ongoing change, albeit subtle, may have contributed to his improved performance. Another confound inherent in many repeated measures designs, and particularly multiple-baseline designs, is the effect of practice. As noted previously, the increase in PIQ from Baseline 1 to Baseline 3 may have been partially due to a practice effect. However, given the defective nature of his original performance and the fact that he did not demonstrate such an effect on visual memory tests suggests that the contribution of practice to the increase in his test performance was, at most, modest. Conversely, practice and learning were crucial components of the treatments aimed at improving his functional performance (i.e., physical and occupational therapy), and the gains he demonstrated in the functional realm were to a large degree dependent on his capacity to learn to compensate for his left hemivisuospatial inattention.

The demonstrated increase in compensation for left hemivisuospatial inattention and visuoconstructional ability are particularly striking in light of the 20% reduction in right cerebral blood flow (Figure 2), which suggests a comparable reduction in right cortical metabolism. It is important to note that the patient improved significantly in selective areas of cognitive processing and realized considerable gains in functional performance, despite ongoing thalamocortical hypometabolism. However, it is equally important to note that impairments in other functions, both treated (i.e., visuo-perceptual processing) and untreated (e.g., visual memory) persisted. Overall, these findings suggest that even severely impaired patients with right hemisphere stroke may benefit from structured cognitive intervention directed toward the compensation for left hemivisuospatial inattention, and that this benefit can be demonstrated 6 months after onset.

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