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Microcomputer-based cognitive rehabilitation of visual neglect: three multiple-baseline single-case studies

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Cognitive remediation programmes were delivered by microcomputer to three patients showing visual neglect using single-case experimental methodology with multiple-baseline across-function designs. The patients included one head injury case and two cases of cerebrovascular accident. Clear differences were produced in target functions. The most likely mechanism for this change was the learning of new verbal regulation strategies, although other, non-verbal, mechanisms may have been involved.

Unilateral visual neglect is a common result of cerebrovascular accident [1] and visual-perceptual difficulties have been documented following head injury. Perlin *et al.* [2] reported that 19 out of 39 head injury patients surveyed 'warranted the services of a rehabilitative optometrist'. Brooks *et al.* [3] found that visual problems were frequently reported (although not necessarily always severe) in severely head-injured patients up to 7 years post-injury. While overall estimates are not available of the frequency of occurrence of visual neglect following head injury, it is the case that many patients suffering from neglect, as well as their relatives, interpret such problems as visual rather than cognitive, and it is possible that some cases of visual neglect go undetected for this reason.

Cognitive rehabilitation for visual neglect has been evaluated by, among others, Weinberg *et al.* [4], Gordon *et al.* [5] and Webster *et al.* [6]. Training procedures have included scanning training, 'end-anchoring' procedures, line bisection training, size estimation and spatial location training. Promising results have emerged from some of these studies, suggesting that visual neglect is partially remediable.

The role of microcomputers in cognitive rehabilitation has not been subjected to controlled investigation until recently, when Sohlberg and Mateer [7] showed improvements in attentional functioning in head-injured patients using a multiple-baseline design, following microcomputer-based attentional training. The present paper reports three multiple-baseline single-case studies aimed at training compensation strategies for unilateral visual neglect in one head-injured and two stroke patients.

The reason for considering the use of microcomputers in the rehabilitation of neglect are as follows. Firstly, they can administer a given exercise a large number of times without

fatigue or boredom. They can also present tasks of very short duration which may reveal deficits not apparent using traditional assessment methods; the corollary of this is that they can train responses within time parameters which could not feasibly be controlled by human teachers. Finally, they can automatically adjust task level to individual performance by means of rapid scoring and calculations which would not readily be done by a trainer.

There are potential problems in using microcomputers for such purposes, however. Perhaps the greatest of these is that brain-injured people may be encouraged to waste their time doing banal and fruitless exercises when they could be spending valuable time and money learning more practically relevant and socially useful skills. The patient may be persuaded that increased scores on a given task or game reflect some enduring and general recovery rather than a task-specific practice effect. This in turn may lead to a damaging delay in patients and their families coming to accept the reality and relative permanence of their cognitive disabilities, with all the emotional and relationship problems which may ensue. For these reasons evaluation is crucial in advance of widespread use, though unfortunately this has rarely taken place.

Finally, it is important to specify the theoretical rationale underpinning any attempt at cognitive rehabilitation. Three broad categories of rationale can be identified. The mental exercise model assumes that practice of a given mental function may improve that function. Most informed commentators doubt that this has much validity (e.g. ref. 8). A behavioural shaping model uses the established principles of learning, shaping, fading, chaining, intermediate goals, intermittent reinforcement, etc. to try to increase the probability of a given response. The functional reorganization model asserts that improvement occurs because the goal in question is now achieved by a different arrangement of (undamaged) residual mental functions, and trainers using this model try to specify what alternative neuropsychological process is mediating the improvement, and indeed attempt to foster that process through a specific training procedure. This is the classic approach of Luria [19] and is the one favoured by the same commentators who are dubious about the 'mental muscle' model [8].

Case studies

A multiple-baseline-by-function design is used. At least two impaired but independent cognitive functions are measured over a baseline period, and then one of these is targeted for training. Improvement on the targeted measure in the absence of improvement in the non-targeted measure adds some control to a simple pre-post design, although further study is required to ensure that any obtained positive result is replicable.

Case 1

This 20-year-old student suffered a head injury in a road traffic accident. Glasgow Coma Scale score on admission was 3, and duration of post-traumatic amnesia was 2 weeks: both testify that this was a very severe injury. CT scan showed widespread contusions in the basal ganglia, with effacement of the third ventricle. He was ventilated for two weeks, having suffered a cardiac arrest 2 days following the accident. Ophthalmological examination 2 months post-injury revealed normal vision in the right eye, but only 6/9 in the left eye. He showed no field defects according to this report, no diplopia and full ocular movements.

He was assessed neuropsychologically 2 months post-injury. Concentration and verbal memory were satisfactory inasmuch as backward digit span and Logical Memory (from the Wechsler Memory Scale) scores were above the mean for his age. He made frequent errors

reading a passage from a newspaper, tending to misread the left half of each word. He also showed visual-perceptual problems in the form of a distorted copy of one of the Bender-Gestalt figures, and clear left-sided omissions on copying of the Rey-Osterrieth figure [10]. On a computerized test of visual scanning ('Search for the Odd Shape') [11] he showed 100 per cent longer latencies for detecting a target stimulus in the left visual field compared with the right visual field.

Baseline was four sessions spread over 6 days. Following the last of these sessions the intervention took place, and consisted of the procedure described below. Testing took place at the beginning of each session, so as to eliminate any immediate effects of the training.

A simple training programme was devised, based upon the programme 'Search for the Odd Shape' (SOSH) by Gianutsos *et al.* [11]. This programme presents an array of identical shapes, with the exception of one shape which is slightly different. This odd shape appears an equal number of times on the left and on the right of the screen, and the subject's task is to press a key as soon as it is seen. He then indicates its position and the tester scores it 'right' or 'wrong' on the computer. After 16 trials the median search times for left and right halves of the field are presented.

The aim of the training programme was to establish a verbally regulated motor habit for orienting leftwards. The 'mental prosthetic' in question was based on intact verbal processes and on intact abilities for cued eye, head and attentional shifts towards the left. After the baseline period the subject was shown the printout showing left-right differences in latency, and the goal of equalizing these latencies was explained to him. He was told that the system in his brain which automatically directed him to notice things to the left was not functioning properly, and that he had to learn a new way of doing this using verbal instructions, as well as eye and head movements, which it was hoped would become an automatic habit which would serve him in his day-to-day activities.

The training method was a simple self-instructional procedure based on the work of Meichenbaum and Goodman [12]. First the command 'look left' was spoken loudly in his ear just before the shapes appeared. This was continued for three sets of trials, by which time the left-right latencies had reduced considerably. Then the command was spoken quietly for a further number of trials until this, too, produced lowered left-right discrepancies. The patient was then required to speak out loudly the same words, but had initially to be verbally cued to do this by the trainer. This cue was faded out until the subject was saying 'look left' without cueing. The next stage was to have the subject speak quietly, and the final stage required sub-vocalized self-commands. This took place over six treatment sessions, twice daily, for 3 days, lasting approximately 45 minutes each, following a baseline period of 2 days (four assessment sessions).

In addition, feedback was given to this subject about his tendency to misread words because of his misperception of the left-hand side of each word. He was instructed in future to try to fixate the left extremity of each word, rather than on the middle. A modified self-instruction procedure appropriate to this task was used. Words were presented to him using the 'Speeded Reading of Word Lists' (SRWL) programme developed by Gianutsos and Klitzner [13]. Single words were exposed for 0.9 seconds, and strings of five words for 4.5 seconds per string. His task was simply to read words as they were presented, while focusing on the left side of each word rather than the middle. This task was presented in this form as it was thought that such a compensatory habit would have to be learned under time pressure if it was to be useful in conditions of normal reading.

Two measures were taken on each of the four baseline and five training sessions. The first of these was the target measure, which in this case was accuracy of reading lists of words presented in paper. Nine lists generated from the Gianutsos and Klitzner [13] lists were used,

one for each session, and none of these coincided with the words used in training. The second measure was accuracy of copying one item of the Bender Gestalt test which Diller *et al.* [14] showed to be most highly correlated with the total Bender score. The scoring procedure of Diller *et al.* was used, and a total distortion score obtained for each copy. This test was not expected to improve as it measured a visuospatial and attentional capacity which was not targeted by the training.

Figure 1 shows that the reading errors declined considerably following intervention, while the Bender test remained relatively unchanged. Although these data were obtained from two sets of readings from non-randomly allocated points, for descriptive purposes a Mann-Whitney U test was carried out comparing the baseline and training data. The difference between the two phases on word reading was highly significant ($U = 0, p < 0.001$) while the difference for the Bender figure was not significant ($U = 10, p > 0.05$).

In conclusion, this case study suggests that some aspects of reading difficulties associated with unilateral visual neglect, and also possibly with a foveal field defect, may be ameliorated using a simple scanning and self-instructional procedure.

Case 2

This 55-year-old mathematics teacher had suffered a right middle cerebral artery area infarction confirmed by CT scan. He was assessed 23 weeks following his stroke, at which time he showed a dense left hemiparesis; a left homonymous hemianopia, as well as left somatosensory and visual inattention. He had no history of previous brain insult, although he had a 2-year history of problem drinking.

On neuropsychological assessment he had particular difficulty with the Wisconsin Card Sorting Test [15], poor performance on which is often associated with frontal lobe dysfunction. He showed marked left-sided visual neglect, measured by the Rey copy and by a line bisection task, as well as by the letter cancellation test where he showed mainly left-sided omissions. He also showed severe visuospatial difficulties, left-right discrimination problems, but verbal memory was grossly intact.

Four baseline sessions were set and intervention phase was six sessions. Three target measures were chosen, as well as two control measures. The former were letter cancellation and two new tasks, word search and playing card search. Word search was developed by

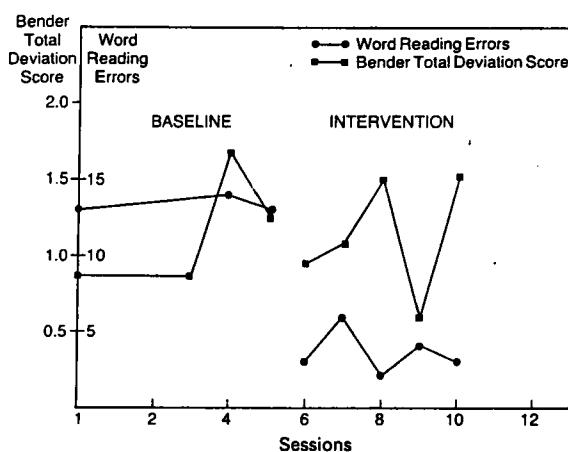


Figure 1. Word reading errors (target measure) and Bender deviation scores (control measure) over baseline and intervention phases (Case 1).

Gianutsos and Klitzner [13] and consists of a 13 by 13 grid of letters on a page within which a three-letter target word is embedded. In ten grids the word is found five times on the left of the grid and five times on the right. Six parallel versions of the grid were devised, and these were given in random order to ensure that no practice effect specific to a particular grid could contaminate the training results.

The playing card search was developed for the purposes of this case study, and consisted of 32 standard playing cards set out on a table in front of the subject. Five cards were randomly selected from those on the left side, and five similarly selected from those on the right. In random order the ten cards were read out in turn and the subject asked to find the card in question. The times taken to locate cards were recorded, and the median times for left and right calculated.

The first of the two control measures was 'motor impersistence', where the subject is required first to close his/her eyes until told to open them, and then to protrude the tongue for a similar period. The score for each is the number of seconds out of 20 that the tongue is withdrawn, or the eyes closed respectively. This test has been described as a measure of non-localized damage to the brain [14] and reflects difficulty in sustained attention as well as difficulties in resisting impulses in favour of a pre-determined plan. The second control measure was the Bender figure used in the previous case. The training procedure used was the same as the first part of the training procedure in Case 1.

Figure 2 shows the left and right latencies over nine sessions on the SOSH task. These scores are based upon the performance during the first trial of each session. During five post-baseline sessions an independent SOSH trial was carried out at the beginning of the session without any instruction being given. A marked reduction in left-right latencies can be seen for the SOSH test sessions between the baseline and training phases respectively. A Mann-Whitney U test was carried out, revealing a significant decline in left SOSH latencies ($U = 2, p < 0.05$). Of course, no conclusions can be derived from this statistic as to the source of this difference: all the statistic does is to provide some support for visual inspection of the results.

Figure 3 shows the scores on the playing card test over the baseline and training periods and it appears that, with the exception of the first training session, a clear improvement in

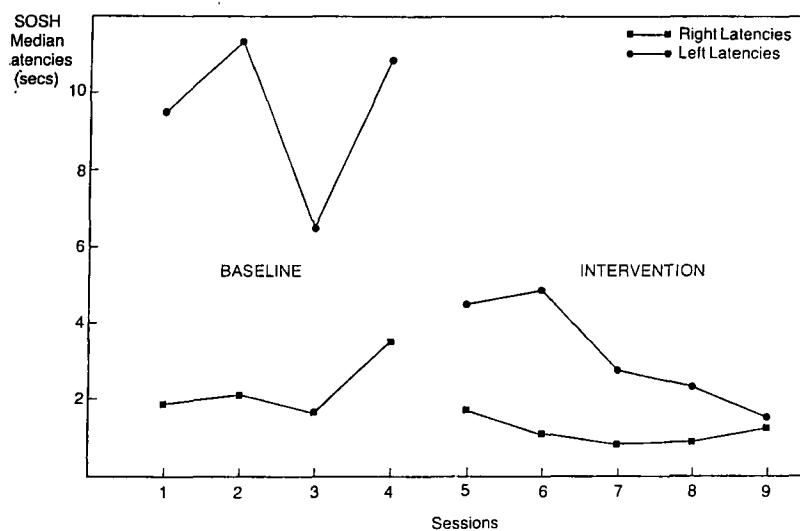


Figure 2. Left versus right latencies on SOSH at baseline and during intervention (Case 2).

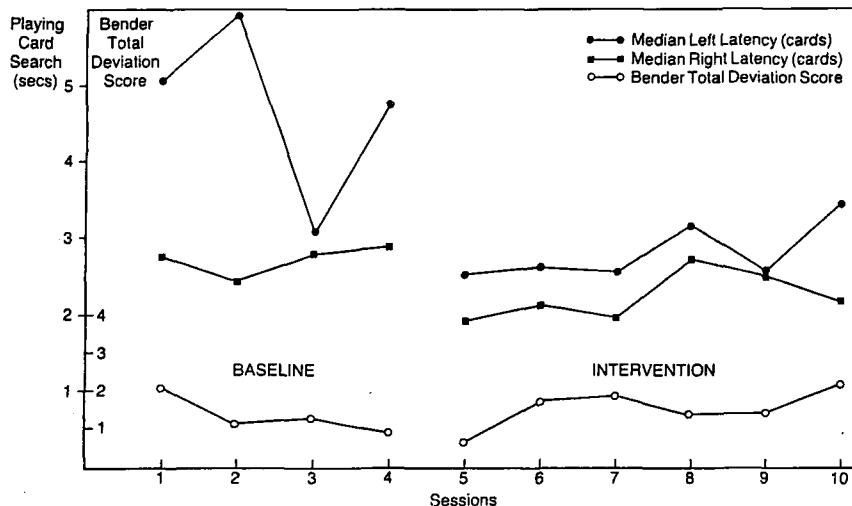


Figure 3. Performance on playing card search (target measure) and on Bender deviation score (control measure) over 10 sessions (Case 2).

performance on this test occurred coincidentally with the training. Used on the same basis as in the previous measure, a Mann-Whitney U test shows a statistically significant difference between the two phases on this measure ($U = 2, p < 0.05$). Figure 3 also presents data on the control measure, Bender distortion. No difference of note was found on these data pre-versus post-training ($U = 9, p > 0.05$).

On the word search task a similar result was found. A reduction in left latencies took place after the first training session, as can be seen in figure 4. Mann-Whitney U test of left latencies pre- versus post-training was statistically significant ($U = 2, p < 0.05$).

Regarding the letter cancellation, it can be seen from figure 5 that there was an improvement in the last baseline session which makes these data difficult to interpret. That

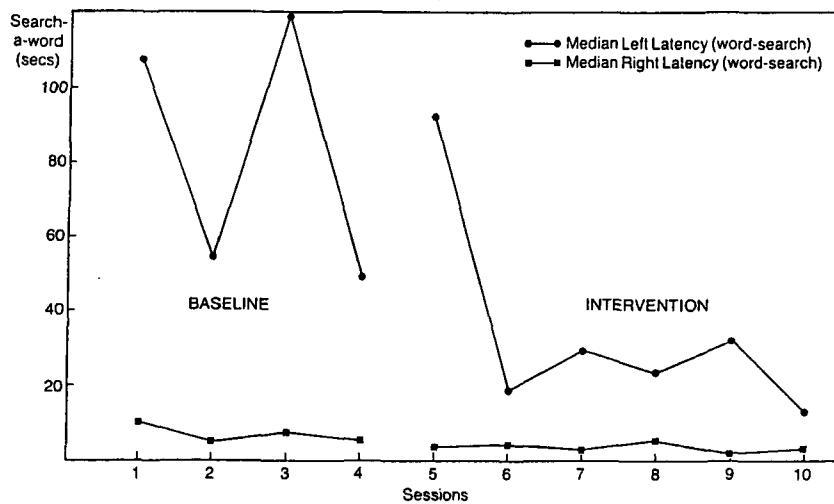


Figure 4. Left versus right search times on the 'Search a Word' task over the 10 sessions (Case 2).

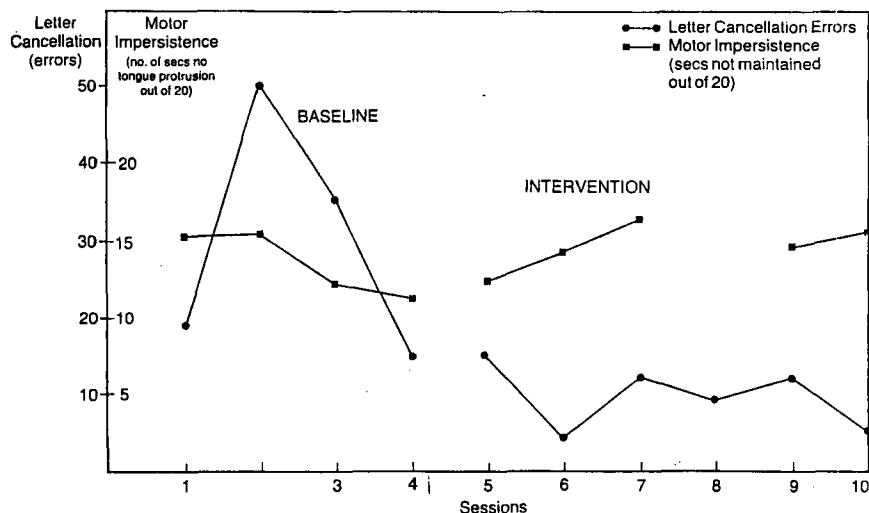


Figure 5. Letter cancellation errors (target measure) and motor impersistence measures (control measure) over 10 sessions (Case 2).

being said, the difference between the two phases was significantly different ($U=0.5$, $p<0.01$). Also in figure 5 are the data on motor impersistence, which showed no significant change over the two phases ($U=9$, $p>0.05$).

In conclusion, this training procedure produced an improvement in functionally relevant target measures. Anecdotally, the subject reported that he could now do the crosswords and word puzzles which were the main way of occupying himself prior to his stroke. He could now look up dictionaries and reference books, which he could not do before. The factors which may account for the changes observed in this case will be considered in the discussion.

Case 3

A 57-year-old woman suffered a subarachnoid haemorrhage and aneurysm thought to be related to eating cheese while on MAO-inhibitors for depression. She suffered a left hemiparesis, left hemianopia (including macular splitting) and showed signs of marked left visual neglect, as well as some left sensory neglect. She had a long history of hypertension and of depression, but at the time first seen she was not clinically depressed.

On formal neuropsychological testing 8 weeks post-incident she read only 26 per cent of words on the Neale Reading Test [16] correctly, and this was entirely attributable to errors of omission on all parts of the prose except the far right. Similarly she copied only 21 per cent of an address correctly and correctly cancelled only 15 per cent of letters on the letter cancellation test used in the previous two cases. Concentration was poor: digit backward score was only 3, and she scored only 30 per cent correct, at a 4-second presentation rate, on the PASAT test of information processing devised by Gronwall and Sampson [17]. She showed no signs of frontal lobe dysfunction and her verbal memory was near average on the Logical Memory subtest of the Wechsler Memory Scale.

Baseline was seven sessions over 1 week, and was followed by a training period of seven sessions over a further 8 days. The target functions of the training were telephone dialling, address copying, letter cancellation, prose reading and word list reading. Parallel versions of

all these tasks were devised: 14 sets of three telephone numbers were given, each of which the subject dialled on successive days; 14 addresses containing identical numbers of characters were used in a similar way; and 14 excerpts of prose from the top levels of the three parallel versions of the Neale Reading Test [16]. Each of the last-mentioned was of approximately the same length, with the score each time being the percentage of words read correctly. For letter cancellation the same test was given on each occasion, as no learning was observed to take place over the baseline period. The word lists used were typed lists of five columns derived from the 'Speeded Reading of Word Lists' programme devised by Gianutsos and Klitzner [13] and the score derived was the percentage of words read correctly. The control measures used were PASAT, Bender copying (as in the previous cases) and Go-NoGo Reaction Time, on all of which the subject was impaired according to the available norms (in the case of the reaction time test used here, on the basis of limited norms collected in the present research project).

Training was based on a programme written for the BBC microcomputer by Robertson and Smart [18]. This task requires the subject to search for the odd one out of a number of 'flowers' on the screen. The programme first teaches the person a systematic scanning strategy using a 'scanning box' which the person moves in a predefined order taught by the computer. The box is moved using a touch-sensitive screen and the person located the odd stimulus by touching it on the screen, following which the computer gives positive or negative feedback. The programme also provides verbal cueing through a speech synthesizer and written commands on the screen. Prior to each trial the person is cued to 'look left' and must, in the early stages, verbalize this response when cued. In short, this programme is an attempt to automate the procedure used in case one. (Fuller documentation of this programme is available from the first author.)

The testing procedure was the same as that used in the previous cases; that is the testing was done before the commencement of each training session. Figure 6 shows two target measures at baseline and at training, namely reading prose and word lists respectively. It is clear that a dramatic reduction in errors took place coincidentally with the onset of training, in the context of stable and non-rising baselines. These differences were both statistically significant ($U=0$, $p<0.001$ for both).

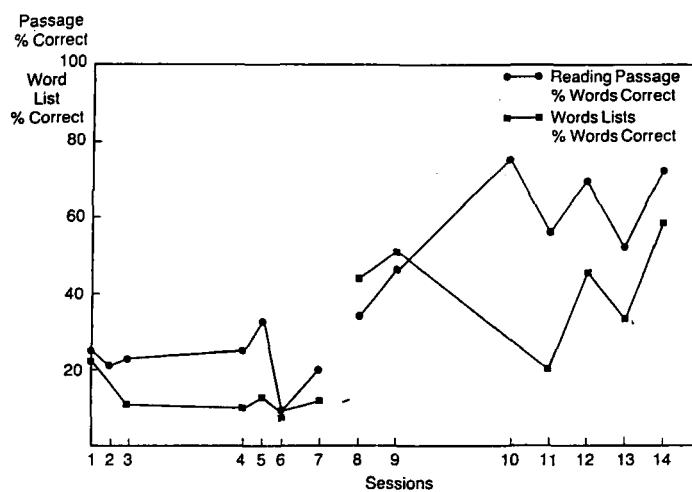


Figure 6. Prose and word reading scores (target measures) at baseline versus intervention (Case 3).

Figure 7 shows performance on telephone number dialling. A clear improvement has taken place at the time of training. Used in the same purely descriptive way as in the previous cases, this difference is highly significant ($U=0, p < 0.001$).

Figure 8 shows performance on a control measure—Bender deviation—which actually deteriorated over time. Figure 9 shows the change in Go-NoGo reaction time, which did not improve during the first three training sessions in spite of improvements on target measures. The difference in this measure failed to reach statistical significance ($U=12, p > 0.05$).

Figure 10 shows the scores on letter cancellation, which showed some evidence of delayed improvement, albeit much less convincingly than on the other measures. The change in letter cancellation was, however, statistically significant in the sense used above ($U=9, p < 0.01$).

In conclusion, the data presented above would be difficult to explain in terms of overall recovery in function because of the sudden improvements in target functions observed in the context of no improvements on impaired control measures. Clearly further research must establish the generalizability of these findings across time and across subjects, but at least some generalization to functionally relevant measures has been observed, using a training procedure totally different in content from the target measures.

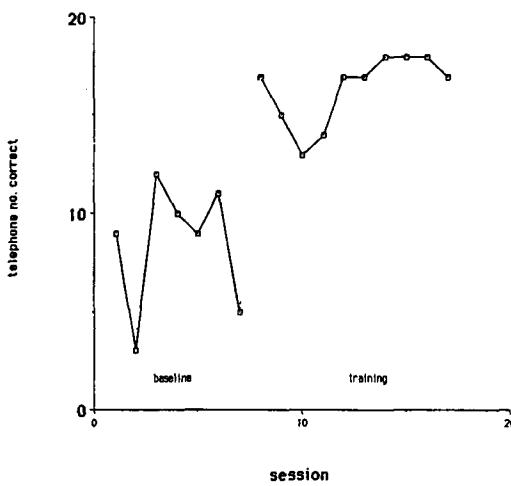


Figure 7. Telephone dialling (target measure), baseline versus training phases (Case 3).

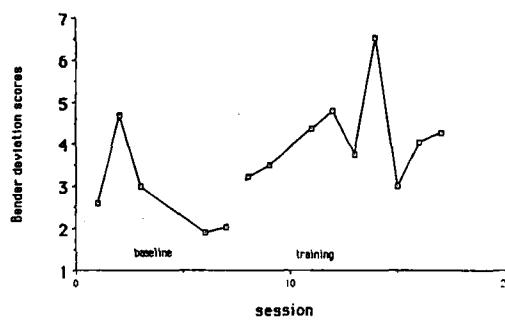


Figure 8. Bender scores, baseline versus training (Case 3).

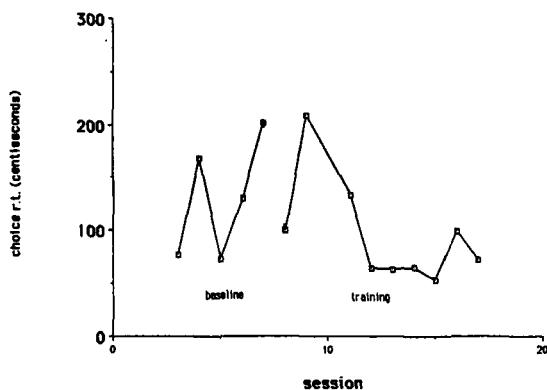


Figure 9. Go-NoGo reaction times, baseline versus training (Case 3).

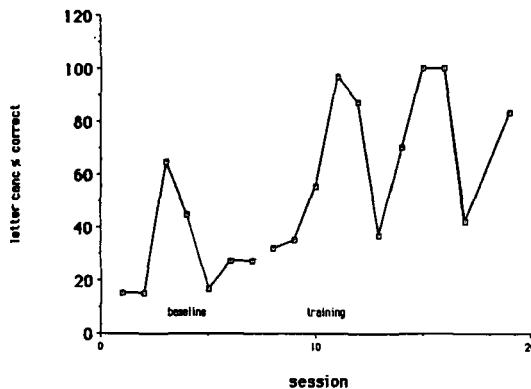


Figure 10. Letter cancellation (target measure), baseline versus intervention (Case 3).

Discussion

In the three cases described above, a degree of improvement in test results related to trained skills was observed alongside little change in untrained skills. One may cautiously argue for a link between the observed improvements and the onset of training, although further replication would be necessary to confirm this conclusion.

The procedures used were relatively straightforward, and it is noticeable that onset of improvements was fairly rapid. What might account for the observed improvements?

- (1) *Underlying general improvement in brain function.* In general the control measures showed no improvements over the period of study. This argues against the idea that improvements on target measures simply reflected underlying improvement in general brain function. Of course these measures do not cover all of cognitive functioning. The fact that Case 2 was almost 6 months post-infarct makes the chance of a sudden improvement at the precise time of the onset of training extremely improbable in this case.

- (2) *Changes in medication or other treatments.* Did the change in performance arise artefactually as a result of change in the subjects' treatment regime? The drug records of these cases show no changes over the period of the study. Similarly, physiotherapy and occupational therapy notes were scrutinized and revealed no change in regime at the relevant times.
- (3) *Sudden comprehension of test instructions.* Were the observed improvements the result of changes relating purely to the proficiency in the tests themselves, rather to any wider improvements in functional status? This is possible, though the fact that it happened roughly coincidentally on different sets of tests in Cases 2 and 3 makes it somewhat improbable. The fact that it did not happen on the control measures further reduces the credibility of this criticism. The target tests were straightforward and simple, and it is hard to see what precisely might suddenly be grasped about the task that was not grasped in the baseline session. On the other hand, the falling baseline on letter cancellation in Case 2 is hard to understand, and must lead to caution in interpreting the results.

Nonetheless, the sudden nature of the improvement remains hard to understand at first sight. Why do many of the changes observed not show a classic 'learning curve', but rather a sudden improvement in performance followed by no further apparent learning? Two other studies in the cognitive rehabilitation literature report a similar phenomenon.

Wilson [19] reported a case of severe apraxia where a shaping and chaining procedure was instituted to train two tasks, namely drinking from a cup unaided and pulling a chair into a table, respectively. What was notable about these tasks was the way in which sudden improvements in performance occurred following just one or two sessions where the subject was guided to do the task. For instance, in the drinking task, step five of the task analysis, 'lift the cup up to your mouth', could only be achieved on the first session with maximum prompting, that is her arm was actually moved through the sequence of actions. By the next session she did this completely alone for the next three sessions with no help whatsoever. Similar patterns obtained in other steps, and the learning seemed to go in quantum jumps rather than graded sequences. Similarly, step four of the chair task, 'grasp the chair', required physical prompting at the first session, but immediately on the next trial was done completely alone and continued to be so for the remainder of the study.

Another study by Wilson [20] reveals a parallel pattern in a case of agnosia, where an agnosic subject was simply told the names of drawings of objects which she could not previously identify on a single trial, and this resulted in 100 per cent correct identification of the stimuli which previously could not be recognized. This method was superior to three other methods involving multiple trials.

Thus it is clear that the present finding of a sudden effect of training is not an anomalous one in the cognitive rehabilitation literature. Theoretically, there is also support for such a pattern. In the case of apraxia, for instance, simply doing an act under external guidance may result in the re-establishment of a connection between the proprioceptive and other feedback stimuli from a given motor act and the mental representation of the act. Until the act is actually carried out, the person remains unable to induce the appropriate motor sequence by the appropriate semantic and intentional cognitions; once carried out, the link between them may be re-learned quickly. Similarly, in the case of agnosia there may be a disconnection between the percept and the semantic label which can be quickly re-established given minimum feedback. The fact that functional behaviours rest on multiple cognitive functions suggests the possibility of rapid re-organization and re-learning given appropriate feedback to the subject.

In the cases of neglect under discussion here, the subjects were given structured feedback and taught simple strategies to compensate, not once, but multiply during the first training session. Case 2, for example, did not attribute his difficulty with reading and reference books to 'slowed left latencies', but rather experienced it simply as a disorganized visual world. Thus it may be that the first training session was sufficient to provide the appropriate corrective feedback as well as to teach an appropriate compensation strategy which was capable of being carried out while leaving sufficient attentional resources to carry out the functional tasks in hand.

The results in the present study compare favourably with the results of Weinberg *et al.* [4], mentioned above, although the measures used here were quite different. Whether the results of this training generalize in time or to a wide range of functional activities must await the results of a randomized controlled trial of this training currently under way.

The question of the theoretical basis for these changes can only be guessed at. Heavy emphasis was placed on self-instructional procedures and the role of verbal regulation of impaired functions is likely to be a strong one, though the increased awareness of deficits produced by the constant feedback may also have been important.

While it appears that microcomputer-based rehabilitation of visual neglect may be of some utility, further research is needed before it becomes widely used. It should never be considered as a substitute for functional training of real-life skills as it is still not clear that the results generalize significantly in time or range of activities.

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