Microcomputer-based Rehabilitation for Unilateral Left Visual Neglect: A Randomized Controlled Trial

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• Microcomputers are widely used in cognitive rehabilitation of brain damage. Unilateral neglect is commonly a target of cognitive rehabilitation, both computer-based and non-computer-based. This study reports the results of a randomized controlled trial of computer-based rehabilitation with blind follow-up for six months. Thirty-six patients with unilateral neglect, as defined by the behavioral subtests of the Behavioural Inattention Test, were randomized into two groups. One group of 20 subjects received a mean of 15.5 (SD = 1.8) hours of computerized scanning and attentional training; the second group of 16 subjects received a mean of 11.4 (SD = 5.2) hours of recreational computing (selected to minimize scanning and timed attentional tasks). Blind follow-up at the end of training and six months after revealed no statistically or clinically significant results between groups. These findings argue against routine clinical use of this type of computerized training until further studies establish what type, frequency, and duration of training produces clinically significant changes in unilateral visual neglect if, indeed, computerized training can have an effect with this type of disorder.

KEY WORDS: Attention; Cognitive; Microcomputers; Rehabilitation; Stroke

Although microcomputers are widely used in cognitive rehabilitation of brain injury,[1-5] no randomized controlled trial of their effectiveness has been published, and very few controlled single-case studies are available in the literature. Robertson and colleagues[6] found that computer-based scanning programs appeared to produce selective improvements on scanning tasks unrelated to the training procedures in three patients with unilateral left visual neglect. Using a multiple-baseline-by-function design, they showed improvements in reading and other daily living activities, eg, telephone dialing. The training procedure consisted of a series of programs which attempted to train systematic scanning anchored on the left (described below).

Sohlberg and Mateer[7] carried out four single-case studies with subjects showing attentional disorder. They used a computer-based reaction time and alternating attention tasks, which included arithmetic exercises, with four brain damaged subjects. A multiple-baseline-by-function design was used, with a measure of attention as the target (Paced Auditory Serial Addition Task or PASAT) and a measure of visuospatial functioning as the control measure. Changes in PASAT in one case were observed, even in the absence of attentional training, and the possibility arises that the apparent improvements in attention arising from training were a result of practice effects on the single measure of attention used. Other studies of cognitive rehabilitation have incorporated computer-based procedures as part of larger programs, but the specific effects of the computerized procedures have never been isolated.[8]

Unilateral visual neglect is a clinical problem to which many computerized programs have been addressed[1,9] in the absence of any randomized group evaluations of their effectiveness. This contrasts with the abundant literature on noncomputerized procedures for rehabilitating neglect, which have generated some promising results.[10-15] Most of these studies found that greater changes in visual scanning could be detected among those given a series of noncomputerized scanning exercises and paper and pencil tasks.

This study is the first randomized controlled trial of purely computerized rehabilitation of unilateral visual neglect to be published, and, as such, it represents a contribution to the knowledge about the effectiveness of this expanding type of rehabilitation.

METHODS

Design

A semirandomized controlled trial of the training was planned, with partial random allocation of subjects to the experimental training and to a control procedure of approximately an equal number of hours of recreational computing. Randomization was done within blocks of severe vs mild neglect patients. Follow-up was carried out by a blind assessor—a research psychologist—at the end of training and six months later. The randomization procedure is described below.

Subjects

Subjects were all patients in Edinburgh hospitals who showed significant unilateral left visual field neglect according to the Behavioral Inattention Test (BIT).[16] The presence of neglect

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was operationalized as failure on at least three out of nine behavioral tests, a cut-off distinguishing neglect patients from controls.[17] All subjects were oriented for time and place, were able to give informed consent for participation in the research, and had the ability to concentrate sufficiently to sit at a computer-based task for at least 15 minutes. Of the 36 patients, 33 sustained CVAs, two had head injuries, and one had had surgery for excision of a meningioma.

Every patient was examined by a consultant neurologist; on the basis of this examination, a "neurophysical scale" score was calculated for each subject.[18] This scale quantifies, in standardized form, data obtained from conventional neurologic examinations, and it includes ratings of sensory and motor deficits, cranial nerve deficits, presence of abnormal reflexes, and other relevant variables. Summaries of the demographic, medical, and neuropsychologic data for the two groups are shown in tables 1 and 2. There were nine men and 11 women in the experimental group, and ten men and six women in the control group.

Tests

A wide range of psychologic and neuropsychologic tests were given at intake, immediately after training, and at six-month follow-up. Assessment of neglect rested on a subset of these tests. The BIT was the principal outcome measure used; it was chosen because it is the first adequately standardized test of neglect which rests on a range of measures closely related to real-life functioning (eg, dialing a telephone, reading a menu, picking up money). Given the rehabilitation aims of the programs used here, this was regarded as an essential test.

The other tests of neglect were chosen on the basis of being widely used, well standardized tests, sensitive to neglect, which would allow the patients in this study to be compared with those in other studies. These tests were the picture completion and block design subtests of the revised Wechsler Adult Intelligence Scale (WAIS = R),[19] the Neale Reading Test,[20] a letter cancellation test,[10] and an observer's report of neglect,[16] included to try to assess generalization of any treatment effects. The Rey-Osterreith Test[21] was also included because of its drawing task; drawing is widely used in the assessment of neglect. The memory part of this test was not included as a key neglect indicator because lateralized omissions on recall would depend heavily upon lateralization of omissions on copy that the measure would be redundant. Although the line orientation test[22] was given (only at intake), it was not used as a measure of neglect because, for reasons unrelated to this study, the administration of this test was amended to minimize the influence of neglect on the final score, thereby maximizing nonlateralized visuospatial representation ability on the score.

Relatively greater improvement of the experimental group over the control group on the above seven measures of neglect was hypothesized. Other tests given to ensure matching of groups on relevant variables included the General Health Questionnaire,[23] the Social Behaviour Assessment Schedule,[24] the Frenchay Activities Index (a measure of participation in leisure and self-care activities),[25] the National Adult Reading Test,[26] the digit span subtest of the WAIS = R,[19] the Cognitive Awareness Test,[3] the Wechsler Logical Memory Test,[27] the Wisconsin Card Sorting Test,[28] the PASAT,[29] and the motor impersistence test.[10] These were given at all three data collection points. In addition, a crude index of psychotropic drug consumption in the training period was devised based on the percentage of weeks while training in which the patient was receiving either constant, intermittent, or no medication in each of four categories of potentially psychotropic drugs. (Details of this scoring procedure are available from the authors.)

Training Procedure

The principal of four suites of programs used was a scanning training program administered on a BBC Acorn microcomputer using a 22-cm by 28-cm monitor with a Microvitec touch-sensitive screen. Shapes were presented on the screen, and all of them were identical except one. The subject identified the one which was different and identified it by touching the screen where feedback was given. The nature of the shapes could be varied and combined with different odd shapes, and the total number of shapes could be 4, 16, or 64. A voice synthesizer cued the subject to "look left," and subjects were encouraged to verbalize this. A flashing left-pointing arrow with the words "Look Left" prominently displayed also appeared with the other cues before presentation of each task.

All this took place against a background of intensive briefing about the nature of the subjects' problems, as well as showing them left-right discrepancies in their latencies in the assessment phase. In this program, the computer displayed bar charts, illustrating in comprehensible form the difference in

Table 1: Means and Standard Deviations for Selected Demographic, Medical, and Psychologic Variables for Experimental and Control Groups

	Experimental ($n = 20$)		Control ($n = 16$)				
	Mean	SD	Mean	SD	*df*	*t*	*p*
Age	64.2	12.6	63.1	9.6	34	<1.0	>.1
Onset of neglect (wks)	19.2	21.1	10.8	6.3	34	1.6	>.1
Neurophysical scale	9.7	3.5	11.5	2.9	33	1.6	>.1
Frenchay Activities Index	8.9	9.7	6.5	7.0	33	<1.0	>.1
GHQ*	25.5	14.3	18.3	8.2	33	1.8	.09
SBAS†	3.9	3.4	3.1	3.3	33	<1.0	>.1
Hours computing	15.4	1.8	11.4	5.2	34	3.2	.003
Other therapy (hrs)	4.8	3.1	5.6	2.8	33	<1.0	>.1
Drugs‡	167	156	236	162	25	<1.0	>.1

*GHQ = General Health Questionnaire; †SBAS = Social Behaviour Assessment Schedule; ‡Based on index of psychotropic drugs consumption described on page 664 above.

Table 2: Means and Standard Deviations for Neuropsychologic Variables for Experimental and Control Groups

	Experimental ($n = 20$)		Control ($n = 16$)				
	Mean	SD	Mean	SD	*df*	*t*	*p*
National Adult Reading Test	106	5.8	105	7.6	34	<1.0	>.10
Forward digit span	6.0	1.1	5.8	0.9	34	<1.0	>.10
Backward digit span	3.8	1.9	3.7	1.4	34	<1.0	>.10
Orientation	98.7	2.0	98.4	3.1	34	<1.0	>.10
Logical memory, immediate*	8.3	3.5	7.1	2.1	34	<1.0	>.10
Logical memory, delayed*	5.0	3.3	3.8	2.2	34	<1.0	>.10
Rey-Osterreith Test							
Complex figure copy	21.6	12.4	25.7	23.4	34	<1.0	>.10
Delayed recall	10.3	8.7	8.7	6.8	34	<1.0	>.10
Word fluency	23.7	7.9	21.8	8.0	34	<1.0	>.10
Wisconsin Card Sorting Test†	58	33	41	32	32	1.48	.15
PASAT	22.2	10.7	23.0	10.9	32	<1.0	>.10
Neale Reading Test							
Accuracy	31.0	34.6	26.6	35.4	34	<1.0	>.10
Comprehension	2.9	2.1	2.9	2.5	34	<1.0	>.10
Letter cancellation test (total errors)	42.7	32.5	62.4	31.5	32	1.32	.17
Handedness	67.2	6.7	66.5	5.4	34	<1.0	>.10
Benton line orientation test	11.3	6.1	10.7	4.2	29	<1.0	>.10
BIT	48.8	22.4	45.9	23.8	34	<1.0	>.10
Motor impersistence	29.8	13.3	28.6	11.6	34	<1.0	>.10
Observer's report of neglect	8.4	4.5	8.2	4.2	30	<1.0	>.10

* Wechsler memory scale; † Nelson version, % perseverative errors

left-right latencies; thus, this aspect of the training procedure was also semiautomated, albeit with intermittent trainer reinforcement and encouragement.

Also in this program, a horizontal and vertical line bisection task enabled the subject to create four screen quadrants. Subjects then underwent an automated training procedure to scan the screen, using a scanning window, by touching each of the screen quadrants in a predetermined order. This scanning procedure owes much to the "systematic clockwise scanning" procedure used by Weinberg and colleagues.[30] At the beginning of training, subjects were first given an assessment version of the scanning program. Next, the quadrant creation and quadrant scanning procedures were carried out. Once these had been successfully accomplished, the scanning task was presented again, although this time with the scanning box superimposed on the "odd one out" task. In this final stage, the person carried out this task using the scanning box as an aid. Hence, the subject searched for the odd shape using the box as a viewfinder. Ultimately, this was faded out later in the training, and elements of the cueing were also gradually phased out in the hope that the procedures taught had become internalized as prosthetic strategies. The criterion for fading out the viewfinder and other cueing was that patients started to orient consistently toward the left of the screen in advance of cueing.

The second main suite of programs consisted of a combined scanning and attention program. The program was one where an infinite number of tasks could be programmed into one basic framework. This framework was a target presented at the top of the screen and a series of matching targets and distractors presented below. The task was for the person to locate and touch the targets as quickly as possible, and the responses were recorded via a touch-sensitive screen. Feedback as to accurate detection was given by the computer in the form of auditory and visual reward, and this was related to the speed of response. There is, however, one prerequisite for the computer accepting an accurate response. Before each response, the subject touched a red band at the far left of the screen which immediately turned green. Failure to do this resulted in the computer flashing a message across the screen to "touch left," along with a flashing arrow. The flashing message and arrow continued until the person touched the red band.

An additional feature of the program was that the red band gradually faded away as the person successfully completed a succession of tasks, until ultimately the person touched the screen to the left without any visual cue there. This fading was carried out automatically by the computer program, using the criterion of 10% reduction in cueing bar thickness for every set of trials where there was no reminder given by the computer to touch the bar. This was a computerization of the "end-anchoring" procedure used for reading training by Weinberg and associates.[14] As in the case of the scanning program described above, after each cycle of trials the computer presented a vivid bar chart showing left vs right latencies, and the person was briefed as before to try to equalize them. As the left latencies approached the right latencies at a given difficulty of task, the difficulty was increased. The tasks ranged from simple object matching tasks to ones requiring calculation. For instance, one of the latter presented as the target at the top of the screen "numbers divisible by 9," and the screen display consisted of an array of numbers, some divisible by 9 and some not. Two other sets of programs used included a set of attention training tasks, consisting of reaction time and vigilance type, described elsewhere.[31]

The training time was set at 14 sessions of 75 minutes each, usually two times per week for seven weeks. This time was a function of staff time and transportation resources available, but, also, it was close (17.5 hours) to the 20 hours of training which Weinberg and associates[14] found to be effective in producing detectable improvements in neglect. Problems with transportation and other difficulties led to deviations from this plan, however. Only one in the experimental group received less than ten hours of training; this was also the case for nine in the control group; 11 in the experimental group received more then 15 hours of training, but only three in the control group received this much. The mean number of hours training for the experimental group was 15.5 (SD = 1.8) and for the control group 11.4 (SD = 5.2). This is a statistically significant difference ($t = 3.2$, $df = 34$, $p < .003$).

Control procedure

The aim for the control group was to control, as far as possible, for the nonspecific novelty and halo effects of the research. It was considered important that the subjects be exposed to plausible computer activities, but that there should be no potential neuropsychologic mechanism by which these activites could improve cognitive function. Thus, word games, such as anagram tasks, quizzes, and simple logical games such as "reds and greens," were included. As theses programs were already in use by occupational therapists in various hospitals in Britain, their use was felt to be justified in terms of ethical acceptability and in terms of plausibility of the programs to the subjects taking part in the trial. The main exclusion criteria for such programs were if they included any speed component which might mimic a reaction time task, or if they included tasks with a large component of visual search which might increase awareness of neglect and foster compensatory scanning.

RESULTS

Table 1 shows the data on a number of nonneuropsychologic, demographic, and treatment variables for the two groups. The table shows that the groups were reasonably well matched for age, social behavior, drug intake while training, hours of therapy per week, depression, and level of activities at intake, as well as on a range of other variables. The only statistically significant difference between groups was that the experimental group had more hours of computer therapy than the control group ($t = 3.2$, $df = 34$, $p < .003$).

Table 2 shows that there were no statistically significant differences between the two groups on any neuropsychologic variables. Trends were apparent for the experimental group to be more impaired on the Wisconsin Card Sorting Test (percent of perseverative errors) and less impaired on letter cancellation errors. It is possible to conclude that the randomization successfully produced two well-matched groups for the study.

First Follow-up Data

Three of the 36 subjects could not be followed up, one because of death and two because of refusals. Table 3 shows the follow-up information taken immediately after training for the two groups. All the variables selected to measure changes in neglect are shown. The principal of these is the BIT, which showed no statistically significant difference between groups. No significant differences were observed in reading, letter cancellation, Rey-Osterrieth copy, block design, or observer reports of neglect. Only the picture completion test showed a statistically significant difference ($t = 2.5$, $df = 31$, $p = .018$).

Table 3: Means and Standard Deviations for Selected Outcome Variables for Experimental and Control Groups

	Experimental ($n = 20$)		Control ($n = 16$)				
	Mean	SD	Mean	SD	df	t	p
BIT	52.0	24.0	59.9	20.2	31	<1.0	>.10
Rey-Osterreith complex figure copy	25.9	13.4	20.7	11.6	31	<1.0	>.10
Neale Reading Test accuracy score	20.1	26.1	9.2	16.5	26	1.2	>.10
Letter cancellation test total errors	43.4	30.4	43.2	28.3	31	<1.0	>.10
WAIS-R subtests							
Picture completion	7.5	2.8	5.1	2.5	31	2.5	.02
Block design	4.9	2.0	5.3	2.0	31	<1.0	>.10
Observer's report of neglect	6.4	4.8	7.9	3.6	29	<1.0	>.10
Weeks to follow-up	9.2	2.7	9.5	1.8	31	<1.0	>.10

The relationship between hours of computer training and changes in BIT scores was computed using a linear regression analysis. This was done because only hours computing distinguished the two groups. Hours computing explained none of the variance in BIT change scores ($F = .71$, ns). Furthermore, when only the experimental group was selected, there was still no correlation between the hours of training and the change in BIT scores ($F = .31$, ns). Neither did weeks postinjury (where there was a noticeable but statistically nonsignificant difference between groups) explain any of the varaince in BIT change scores ($F = .54$, ns).

Another way of analyzing the results is to calculate the number of subjects in each group who continued to show clinically significant neglect after training. Using the original selection criterion of failure on at least three out of nine BIT tests, 15 of the experimental subjects continued to show this level of neglect at first follow-up; only five moved out of this category. Among the controls, eight still showed this level of neglect, five had passed below this threshold, and three were lost to follow-up.

Analysis by Subgroups

A subsidiary question was whether there was a treatment effect for patients with severe neglect, which may be obscured by a lack of effect for the mild neglect patients. Thus, patients with a BIT score of more than 70 (representing a little less than one standard deviation above the mean score for the sample) were excluded, and the comparison of experimental ($n = 17$) and controls ($n = 10$) in this category was repeated for BIT scores at first follow-up. No differences emerged ($t = .36$, $df = 25$, ns), and there were no significant differences on any of the other neglect variables.

Secondly, those patients who showed cognitive deterioration during training were excluded. This was defined as a reduction by at least one standard deviation on at least two of the following tests: logical memory (immediate recall), orientation, and Wisconsin perseverative errors. Eight subjects who were considered by these criteria to have deteriorated cognitively (five experimental and three control) were excluded. No significant differences on any of the outcome variables emerged between treatment groups in the remaining patients.

Table 4: Means and Standard Deviations for Neglect Variables for Experimental and Control Groups at Six-month Follow-up

	Experimental ($n = 20$)		Control ($n = 16$)				
	Mean	SD	Mean	SD	*df*	*t*	*p*
BIT	60.1	18.6	61.8	21.5	25	<1.0	>.10
Rey-Osterreith complex figure copy	29.7	11.3	26.8	11.8	24	<1.0	>.10
Neale Reading Test accuracy score	6.2	9.1	14.9	23.0	23	1.36	>.10
Letter cancellation test total errors	20.0	16.4	23.1	14.5	25	<1.0	>.10
WAIS-R subtests							
Picture completion	7.2	2.9	5.9	1.5	22	1.6	>.10
Block design	4.9	3.2	4.4	1.8	24	<1.0	>.10

Six-month Follow-up

A six-month follow-up was carried out when possible. A total of 27 subjects were followed up, with the loss from the previous assessment being due to refusals, address changes, and illness. The assessment was the same as the first follow-up, and the assessor was, as before, blind to group assignment. Insufficient relative reports were obtained for inclusion of the observer's report of neglect measures.

Table 4 shows the results on neglect-related measures for the two groups at the second follow-up. No significant differences between groups existed on any other outcome measures. Neither group appeared to show any greater cognitive deterioration than the other; for instance, the logical memory scores did not differ significantly ($t < 1.0$). The difference in picture completion scores had also disappeared at the second follow-up.

Again, using the original selection criterion of failure on at least three out of nine BIT tests, 14 of the experimental subjects continued to show this level of neglect at the second follow-up (compared to 15 at the first follow-up); four showed levels of neglect below this threshold and two were not followed up. Five of the controls still showed neglect (compared to eight at the first follow-up), four showed no neglect, and seven were lost to follow-up. Thus, the control group showed a greater proportion of improvement than the experimental group, although this may not be a valid conclusion given that more controls than experimentals were not followed up.

DISCUSSION

The hypothesis that the computerized training procedure would result in a significant reduction in neglect of the experimental group over the treatment group was not confirmed. The findings of Weinberg and colleagues[15,30] that neglect rehabilitation produced the most marked results with the more severely affected patients lead to a subanalysis of the severe group in our study, with no alteration in the initial finding. Similarly, exclusion of patients showing cognitive deterioration failed to yield any difference between groups.

Less than a third of the subjects showed recovery of neglect within the first follow-up period, and further significant improvements in this rate were not observed over a six-month period, although this is a tentative conclusion because of the lower follow-up rate for the final assessment. The level of neglect did not rise to any clinical significance, on average. The mean scores on the BIT, which has been shown to be a reliable measure of neglect,[16] rose from a mean of 46.9 (SD = 22.4) at intake, to 56.5 (SD = 20.5) at first follow-up, and 60.6 (SD = 19.2) at final follow-up, each out of a maximum possible 81.

Training had no appreciable effect upon this rate of recovery, and the fact that the control group actually had significantly less training than the experimental group strengthens this conclusion. In spite of the latter group receiving more hours of training, as well as a greater sophistication of therapy, no significant differences emerged.

The absence of a no-treatment control group makes it impossible to completely exclude the possibility that both the experimental and control training procedures led to equivalent improvements in neglect, although the fact that no large improvements in neglect were observed for either group weakens this argument. Also, the control training procedures were of a sufficiently general nature (eg, quizzes and anagram tasks) that if they, in fact, did have the influence on neglect suggested by this interpretation, general occupational stimulation rather than specific neuropsychologic training would emerge as the preferred treatment for neglect, given that the former requires no specific training for therapists and is less arduous for patients. Nevertheless, the methodologic weakness imposed by the existing two-group design remains, and future studies would do well to incorporate a no-treatment group, although only multifacility trials could readily generate the necessary sample size for a three-group study.

The main finding of this study is difficult to reconcile with the single-case studies published previously.[6] A number of explanations are possible, including small generalization of training effects to the sample population, short-lived treatment effects, and inadequacy of the single-case study designs used. Some might also argue that the particular computer programs used in this study were ineffective, and that more suitably designed programs would achieve significant effects. This is, of course, possible, although the complete lack of any significant effect with the suite of programs used here should warrant caution in advocating this type and frequency of therapy to neglect rehabilitation. Certainly one would not be justified in recommending routine use of these programs with neglect patients for purely clinical purposes.

The possibility that more intensive treatment, both in terms of frequency and total duration, would be necessary to show any significant effects also arises, although this remains to be demonstrated. In any case, it would seem to be more desirable to spend valuable therapy time directly training functions of everyday use (such as reading) to the patient, in the manner of Weinberg and colleagues,[14,15] rather than carrying out repetitive and unproven exercises on a standard-sized computer screen which encompasses only a small part of the functional visual-attentional field of the neglect patient.

This last point is strengthened by the findings of a study by Gouvier and associates,[12] who found that training effects on various noncomputerized exercises showed up consistently only on tests which were similar to the training procedure. For example, lightboard training of the type developed by Weinberg and colleagues[14,15] did not cause impressive improvements in letter cancellation, and training in cancellation tasks did not produce clear and consistent effects on lightboard test performance.

If leftward attentional and oculomotor scanning do become associated with specific stimuli, then lack of generalization of the above type should not be surprising, and there arises the need for training in the presence of stimuli which will appear in the everyday life of patients. Computer screens do not usually provide such stimuli, and the role of microcomputers in the rehabilitation of neglect remains to be demonstrated.

In a sister study to this one, carried out by the same authors using an identical design (unpublished observations), a mixed group of stroke and head injured patients showed little change in attentional problems at first follow-up,[31] but they did show a significant group effect at six-month follow-up. The experimental group showed significantly greater improvements on PASAT, as well as on the block design, digit span (backward), arithmetic, and picture completion subtests of the WAIS-R compared to the control group. Therefore, microcomputers may, in the long term, prove to have more of a role in some areas of cognitive dysfunction than in others.

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