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The treatment of visual neglect using feedback of eye movements: a pilot study

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Summary

Feedback of eye movements was evaluated as a treatment for visual neglect in right hemisphere stroke patients. Patients with visual neglect identified on the Behavioural Inattention Test (BIT) were randomly allocated to two groups. One group ($n = 9$) was treated for 2 h 40 min a week for 4 weeks, by wearing glasses which provided a reminder bleep if patients failed to move their eyes to the left in a 15 s interval. The control group ($n = 9$) received no treatment for their visual inattention. Comparison of the groups after 4 weeks treatment and a further 4 weeks follow-up showed no significant difference either in eye movements or on the BIT. However, there was a trend towards a difference between eye movements in the two groups at 8 weeks, suggesting treatment may have influenced eye movements without changing neglect.

Introduction

Visual neglect is a common problem following hemisphere stroke,[1] and one which is associated with a poor rehabilitation outcome.[2–5] Many rehabilitation centres provide treatment of visual neglect in order to improve visual neglect and, indirectly, independence in practical activities of daily living.

Various treatments for neglect have been reported, including scanning training[6–12] and caloric vestibular stimulation.[13,14] These have produced variable effects. Diller and co-workers[6–8] have investigated the use of various strategies to increase visual scanning behaviour. These include training on a visual scanning board with a display of lights, having a bright anchor line at the left margin of patients' work, practice on cancellation tasks and making subjects aware of their tendency to neglect one side of space. They have shown that the training improves performance on tasks similar to the treatment activities, but these beneficial effects of treatment are lost once treatment is discontinued. The specific effects of treatment been replicated by some,[9] but not by others.[10]

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Other workers have also found limited effects of techniques to improve scanning. Robertson *et al.*[11] compared practice on computerized activities with recreational computer games for patients with visual neglect. They found no significant differences between two groups of patients on a measure of visual inattention, the Behavioural Inattention Test, or in practical activities of daily living. Towle *et al.*[12] evaluated a perception treatment group in which patients were given 'games' and activities designed to increase scanning, for patients with perceptual problems including visual inattention using single-case ABA experimental designs. The majority of patients did not show any evidence of treatment benefit.

Caloric vestibular stimulation has been suggested as a treatment strategy. This derived from the observation that vestibular stimulation by iced water tends to produce a movement of the eyes towards the stimulated ear. Rubens[13] used this technique with 18 patients with hemianopia and visual inattention following right hemisphere stroke. Patients with right hemisphere strokes received a cold-water stimulus in the left ear and warm water in the right ear. While these stimuli were applied their visual neglect, as assessed on cancellation tasks, was significantly reduced. Similar results were obtained by Cappa *et al.*[14]. The suggested mechanism for this improvement is that the caloric stimulation encourages eye movements towards the left visual field. However, as the effects do not persist it is not a useful rehabilitation technique.

It has been shown that patients with visual neglect do not move their eyes to the visual field contralateral to their lesion. Chedru *et al.*[15] reported that patients with neglect or hemianopia tended to fail to explore the side of space contralateral to the lesion. Ishai *et al.*[16] performed a similar study, but found that patients with right hemisphere lesions and left hemianopia tended to spend more time looking to the left, whereas those with left hemianopia and inattention were no different from normal controls or right hemisphere stroke patients without hemianopia. This suggests that the tendency to look to the left was a strategy to compensate for hemianopia, which did not occur in those with inattention, due to their lack of awareness of the deficit. Fanthome and

Lincoln[17] obtained similar results; they found that patients with right hemisphere stroke without field deficits or neglect tended to look more to the left than normal controls, whereas neglect patients looked more to the right, as did the normal controls. There was no statistically significant difference between neglect patients and controls, though neglect patients tended to look more to the right than controls. Within the neglect group there were some patients who spent more than three times as long viewing the right as the left. The suggestion is that some patients with visual neglect or hemianopia fail to search the visual field. Given that patients with neglect fail to move their eyes, one strategy which might improve visual scanning behaviour is feedback of eye movements. Johnston[18] suggested that feedback of eye movements could achieve the effects of caloric stimulation by encouraging patients to move their eyes without the practical difficulties.

The aim of the study was therefore to evaluate feedback of eye movements as a treatment strategy for patients with visual neglect. The hypothesis was that feedback of eye movements would encourage patients to look more to the neglected hemifield and thereby reduce the visual neglect.

Method

DESIGN

The design of the study was a randomized control trial comparing treatment consisting of feedback of eye movements with a no-treatment control. Outcome was assessed at the end of 4 weeks treatment and 4 weeks later.

SUBJECTS

Subjects were selected from a register of stroke patients admitted to hospitals in Nottingham. The inclusion criteria for entry into the study were: subjects were not blind; they were under 80 years of age; had no history of dementia or psychiatric problems; were not too ill to be assessed; were right-handed; had a score of more than 6 on the Abbreviated Mental Test; had a right hemisphere stroke and scored less than 130 on the Behavioural Inattention Test (BIT).[19] None had received any specific previous treatment for their visual neglect, although all patients were in hospital and receiving physiotherapy and occupational therapy.

APPARATUS

Eye movement recording equipment

The eye movements of all subjects were assessed using a pair of glasses designed by the Department of Ophthalmic Optics at the University of Manchester Institute of Science and Technology. These are based on opticians' trial frames onto which are mounted light-emitting diodes. Infrared light shines on the border between the iris and sclera and is reflected back to the infrared detectors. The amount of infrared light reflected changes as the eye moves. These movements were recorded by a pen recorder to which the glasses were connected.

Treatment equipment

The eye movement detection glasses were connected to a feedback device which delivered an auditory signal, in the form of a continual bleep, if the subject did not look left within a fixed interval. This interval was set at 15 s as this was considered, on the basis of informal pilot trials, to be the maximum length of time a person without visual neglect would continuously look to one side. The signal could be turned off only by subjects moving their eyes left of the midline. The volume of the auditory signal could be adjusted.

PROCEDURE

Assessment

Subjects' eye movements were recorded while looking at slides. Subjects sat in front of a table with the chin resting on a fixed chin rest. The eye movement glasses were put on and if subjects were shortsighted they wore their own glasses over these. Slides were projected onto a screen, 171 cm in front of them. Subjects were first required to look at a calibration slide which consisted of a central cross ($0{\cdot}5 \times 0{\cdot}5$ cm) and two letters, one on either side of the cross, equidistant from it. The recording was adjusted so that the central position of the eyes corresponded to the midline of the recording sheet, and movements to the right and left of the midline were recorded as deviations from that central line. The projected size of the slides was $48{\cdot}2 \times 36$ cm and the size of each letter as projected was 11×9 cm with letters separated by a 1 cm gap. A line of 25 upper-case letters was presented on three slides. The first was a practice slide and contained three letter A's. The eye movements from this slide were not recorded. The second and third slides each contained six letter A's. The subject was instructed to count the number of A's. The fourth slide was a picture taken from the Western Aphasia Battery[20] which was reversed so that most of the activity was taking place on the left. The fifth and sixth slides were two short passages. The first contained four lines and was justified on the left and right sides and indented 2 cm from the left. The second passage was irregularly indented on the left-hand side and was based on the indented paragraph of Caplan.[21] Subjects were told they would be asked questions about these slides, to ensure they attended to them. Between each of the five target slides, calibration slides were shown. These consisted of a central cross with two letters on either side of the cross and equidistant from it. The calibration slides provided a central fixation point (the cross) from which eye movements could be examined. Eye movements were translated onto a computer disk using a tracer manually, and the area to the left and right of the midline was calculated. The proportion of eye movements to the right or left was calculated using the formula $(R - L)/(R + L)$. This produces a score ranging from -1, which indicates subjects look entirely to the left, through 0, when left and right eye movements are equal, to $+1$, which indicates that subjects look entirely to the right.

Subjects had their eye movements recorded at 4 and 8 weeks after initial assessment. Subjects were also assessed on the Behavioural Inattention Test (BIT)[19] to determine the degree of visual inattention. The BIT consists of six conventional subtests, which are cancellation and drawing tasks, and nine behavioural subtests, which are closely related to everyday activities, including reading a menu, dialling a telephone number and telling the time. The BIT was administered by an assessor who was blind to their group allocation.

Treatment

Those in the experimental group were required to wear the feedback glasses for 2 h and 40 min a week for 4 weeks. This was divided into 40 min a day for 4 days. Subjects usually wore the glasses for 20 min in the morning and 20 min in the afternoon. The glasses were calibrated at the beginning of each session. During the first two sessions the experimenter remained with subjects throughout the treatment time to ensure that they understood the principle of the glasses and responded to the auditory signal each time it came on. At subsequent sessions the experimenter calibrated the glasses and then left the subject. Subjects wore the glasses while sitting in the hospital day-room or beside their beds.

The control group did not receive any treatment for their visual inattention or other perceptual deficits for 4 weeks.

Statistical analysis

Non-parametric statistical analyses were used, as assessments were ordinal scales. Mann–Whitney '*U*' tests were used to compare treatment and control groups. A Friedman two-way analysis was performed to evaluate change over time, and Wilcoxon tests as *post-hoc* tests to evaluate change between two assessments.

Results

Nineteen subjects were recruited for the study; however, as one patient could not be assessed for eye movements because he was unable to move his eyes to the fixation points, 18 patients were studied. Biographical characteristics are shown in Table 1. Mann–Whitney U tests and chi-squared tests showed no significant differences between the groups in their characteristics ($p > 0{\cdot}05$).

No significant differences were found between the experimental and control groups using the Mann–Whitney test at initial or 4-week assessments ($p > 0{\cdot}05$). On assessment at 4 weeks, two subjects in the control group and one subject in the experimental group showed no evidence of visual neglect on the BIT (i.e. a score of > 129) and were excluded from the study. One subject from the control group was excluded as he was discharged from hospital to home outside Nottingham District. Comparison of the remaining subjects at the 8-week assessment showed no significant differences, although the difference for eye movements was close to statistically significant ($p = 0{\cdot}06$). Results are shown in Table 2.

The change over time was evaluated using a Friedman two-way analysis of variance. A Wilcoxon matched-pairs signed-ranks test was used for *post-hoc* comparisons; results are shown in Table 3. At 4 weeks, seven subjects in the control group and six subjects in the experimental group showed less of a rightward bias in their eye movements. There was, however, no statistically significant change over time (Friedman $p > 0{\cdot}05$) in either group. On the BIT Conventional Tests patients in both groups showed significant change (Friedman $p < 0{\cdot}05$). The Wilcoxon test indicated this was significant for both groups between 0 and 4 weeks, and the control group showed significant improvement between 4 and 8 weeks ($p < 0{\cdot}05$). On the Behavioural Tests of the BIT there was significant change in the feedback group (Friedman $p = 0{\cdot}04$). This change occurred between 0 and 4 weeks (Wilcoxon $p = 0{\cdot}03$).

Table 1 Biographical characteristics of patients

	Control group ($n = 9$)	*Feedback group* ($n = 9$)
Age (years)		
Mean	71·1	66·3
SD	7·6	10·7
Range	56–80	49–79
Time post-onset (months)		
Mean	0·6	1·0
SD	1·0	0·7
Range	0–3	0–2
Sex		
Men	6	6
Women	3	3

Table 2 Comparison of treatment groups

	Control group			Feedback group			Comparison	
	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*U*	*p*
0 weeks								
Eye movements	9	0·45	0·52	9	0·47	0·51	38·0	0·83
BIT (Conventional)	9	63·2	45·5	9	69·9	33·7	38·0	0·83
(Behavioural)	9	30·0	26·5	9	23·2	22·9	29·5	0·33
4 weeks								
Eye movements	9	0·42	0·51	9	0·39	0·41	34·0	0·56
BIT (Conventional)	9	90·2	48·4	9	93·4	41·3	40·0	0·96
(Behavioural)	9	42·9	29·3	9	37·6	21·3	34·5	0·60
8 weeks								
Eye movements	6	0·53	0·21	7†	0·17	0·41	8·0	0·06
BIT (Conventional)	6	84·0	50·3	8	97·6	27·9	24·0	0·99
(Behavioural)	6	39·0	26·0	7†	45·1	19·0	18·0	0·69

Eye movements: − 1 = looks only on left; + 1 = looks only on right; 0 = looks equally left and right.
BIT = Behavioural Inattention Test.
†Incomplete data were available for one patient.

Table 3 Evaluation of change over time

	Friedman two-way analysis of variance		Wilcoxon comparison 0–4 weeks			Wilcoxon comparison 4–8 weeks		
	X^2	*p*	*n*	*z*	*p*	*n*	*z*	*p*
Control group								
Eye movements	2·33	0·31	9	− 0·30	0·77	6	− 0·94	0·35
BIT (Conventional)	8·33	0·02*	9	− 2·43	0·02*	6	− 1·99	0·05*
(Behavioural)	4·75	0·09	9	− 1·89	0·06	6	− 1·47	0·14
Feedback group								
Eye movements	3·71	0·15	9	− 1·00	0·31	7	− 1·69	0·09
BIT (Conventional)	8·31	0·02*	9	− 2·52	0·01*	8	− 1·18	0·24
(Behavioural)	6·50	0·04*	9	− 2·19	0·03*	7	− 1·99	0·08
Combined group								
Eye movements	5·50	0·06	18	− 0·89	0·37	13	− 1·71	0·08
BIT (Conventional)	16·20	0·001*	18	− 3·53	0·01*	14	− 2·17	0·03*
(Behavioural)	11·20	0·004*	18	− 2·91	0·01*	13	− 2·50	0·01*

BIT = Behavioural Inattention Test.
* Significant at $p < 0·05$.

Discussion

Feedback of eye movements had no significant effect on eye movements or visual inattention. This may have been because the treatment was not given with sufficient frequency. Although it was anticipated that patients would be able to wear the feedback glasses for long periods, this proved impossible as the glasses were heavy and uncomfortable. Modification of the glasses might make them more acceptable. The glasses were powered by mains electricity and therefore could not be worn during practical activities. If they were portable the treatment could be given for longer, and in a variety of settings, which might enhance generalization of any changes in behaviour achieved.

The lack of significant difference between the groups may reflect the small sample size, and the study did not have sufficient power to detect a difference had it existed. Patients were included in the study with varying degrees of visual neglect and a range of deficits in scanning behaviour. Further selection of patients might have been more appropriate. Chedru *et al.*[15] found asymmetries in exploration time for left and right visual fields only in subjects with marked hemi-inattention. Although on average our subjects tended to spend more time looking to the right, this varied from slight to extreme in degree. If we had selected only those with marked asymmetry of eye movements then the treatment strategy might have been more effective. At eight weeks the difference between the groups approached statistical significance. In this analysis patients who had improved above the criterion for neglect were excluded. It may be that the patients with mild neglect had little scope for improving, and this masked the differences between the groups at 4 weeks. This would suggest there is a specific effect of training eye movements, i.e. patients move their eyes more to the left, but this does not generalize to other measures of visual neglect. This would be consistent with findings of other treatment procedures for neglect.[6–8]

There was little change in eye movements over time, despite a significant reduction in visual inattention. The greatest change in eye movements occurred in the feedback group following the end of treatment. It may be that these patients had learnt a strategy which they continued to apply, and it was only with more time that it became apparent. This suggests that recovery should have been examined over a longer time period.

These results suggest that the nature of the perceptual problems has to be more precisely specified, and treatment adjusted according to the precise nature of the perceptual deficits. Feedback of eye movements did not seem to change eye movements, but this may reflect the nature of the treatment provided; further investigations are necessary.

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