REVIEW

The effect of visual training for patients with visual field defects due to brain damage: a systematic review

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J Neurol Neurosurg Psychiatry 2007;**78**:555–564. doi: 10.1136/jnnp.2006.103853

The objective of this review was to evaluate whether systematic visual training leads to (1) a restitution of the visual field (restoration), (2) an increase in the visual search field size or an improvement in scanning strategies (compensation) and (3) a transfer of training-related improvements in activities of daily living such as reading. To retrieve relevant publications, computer-aided searches of databases (Medline, Embase, Cinahl, Cochrane Central Registers of Controlled Trials) and extensive reference tracing and hand searching were performed. Subsequently, all retrieved and blinded studies were scored on methodological quality. 14 studies were included, 2 randomised controlled trials (RCTs) and 12 within-subject repeated-measures designs (RMD). One of the two RCT studies had good quality. The internal validity of the RMD studies varied from poor to good. Five studies reported a significant effect of the vision restoration therapy (VRT), whereas two studies reported no effect using scanning laser ophthalmoscopy or Goldmann perimetry as outcome measure. All authors of the studies on scanning compensatory therapy (SCT) found a significant effect of up to 30˚ visual search field, a significant increase in reading speed or decrease in reading errors. It is unclear to what extent patients benefit from restoration therapy in relation to a more efficient scanning strategy which enables them to read faster or to avoid obstacles in a better way. No study has given a satisfactory answer. SCT seems to provide a more successful rehabilitation with more simple and user-friendly training techniques. Validated questionnaires provide the most reliable subjective data to assess the transfer of the relevance of training procedures to activities of daily living of the patient. Hence, SCT is recommended until the effect of the VRT is defined.

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Received 5 August 2006
Revised 2 November 2006
Accepted 7 November 2006
Published Online First 29 November 2006

The largest group of visual disorders after acquired brain injury are homonymous visual field defects (HVFDs). Homonymous hemianopia refers to a loss of perception over half the field of vision, affecting both eyes, due to a deficient cortical representation of parts of the visual field or deficient transmission of information from the chiasma towards the visual cortex. Approximately 20–30% of all patients with cerebrovascular infarction requiring treatment in a rehabilitation centre have HVFDs.[1] Some 70% of patients with HVFDs show a spatially disorganised visual search strategy.[2] Such patients have particular difficulties with reading and visual exploration, which have far-reaching, disabling repercussions on their domestic and vocational lives. These percentages indicate the impact of the HVFDs, and how important structured rehabilitation efforts for this group of patients can be.

Since the beginning of the 20th century, efforts have been made to train patients with homonymous hemianopia systematically.[3] Over the past decades, many authors have found evidence that patients may successfully adapt to their HVFDs by training. Some authors claim that their rehabilitation methods lead to restitution of part of the HVFDs.[4–8] According to this view, training reactivates surviving neurons of the partially damaged brain structure itself—that is, the border region (transition zone) or islands of residual vision that exist in some patients with cortical damage. This is also called border shift.[4] Other authors have found evidence that patients may successfully adapt to their HVFDs by compensatory oculomotor strategies—that is, by learning to make large eye movements into the blind hemifield, thereby enlarging the field of search and improving visually guided activities of daily living.[1 2 9–11] Recently, Pambakian *et al*[10] found that patients with lesions <6 months old with HVFDs adapt themselves to the loss of HVFDs (eg, by orienting) in the absence of training. This does not tend to occur in the presence of unilateral spatial neglect.

It is not yet clear whether and, if so, which of these two methods is more effective. Neither is it clear whether the patients benefit from both methods in activities of daily living. There is a debate among authors about what instruments might most accurately measure increase in visual field.[7 12–14] Despite many years of research, there is no consensus on how to determine a border shift. In general, the compensatory strategy method is accepted, but there is criticism about its effect due to a lack of controlled studies.

Hence, a systematic review was conducted of all relevant studies in order to evaluate the effects of visual training for patients with HVFDs. The three main objectives were to review whether systematic visual training can lead to (1) a restitution of the visual field (restoration), (2) an increase in the visual search field size or an improvement of scanning strategies (compensation) and (3) a

Abbreviations: HRP, high-resolution perimetry; HVFD, homonymous visual field defect; RCT, randomised controlled trial; RMD, repeated-measures design; SCT, scanning compensatory therapy; SLO, scanning laser ophthalmoscope; TAP, Tuebinger automatic perimeter; VRT, vision restoration therapy

transfer of training-related improvements in activities of daily living such as reading.

METHODS

Literature search

Relevant publications were identified by means of computerised searches and citation tracking (box 1).

The search strategy included Medline (Winspirs), Embase (Winspirs), Cinahl (Winspirs) and the Cochrane Central Registers of Controlled Trials for the period 1966–2005/07. Furthermore, references of conference reports, references of most relevant studies, citations of most relevant studies and related articles were checked for relevant materials. Vocational reintegration was not included in the search because this term did not provide any useful hits.

Study selection

Studies were selected if they met the following entry criteria: (1) inclusion of only patients with HVFDs due to post-chiasmatic lesions of the visual system after brain injury, documented by CT/MRI scans, and patients with left or right field defects ranging from homonymous quadrantanopia to complete homonymous hemianopia, with and without macular sparing; (2) applying the intervention of vision restoration therapy (VRT) or of compensatory saccadic eye movements and visual search strategies—that is, scanning compensatory therapy (SCT); (3) using the outcome measures of visual field size, visual search field, reading time and reading error, and subjective measures of questionnaires; (4) using the design of RCT, of controlled clinical trial (CCT), of retrospective studies or of RMD studies; (5) using only publications written in English, German or Dutch. The assessment of studies potentially eligible for meeting the entry criteria was done independently by two of the authors (LB and JH). Disagreements were solved by discussion. If disagreement persisted, the judgement of a third reviewer (CL) was decisive. Inter-rater agreement was expressed using Cohen's κ.

Box 1 Search strategy used for computerised searches identifying the design of randomised controlled trials, of controlled clinical trials, of retrospective studies or of repeated-measures design studies

- 1 ''Hemianopia''/all subheadings
- 2 Homonymous hemianop*
- 3 Hemineglect
- 4 Hemianopic dyslexia
- 5 Hemianopic alexia
- 6 Hemianopic reading
- 7 Cerebral blindness
- #8 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7
- 9 Rehabilitation AND hemianop*
- 10 Treatment and hemianop*
- 11 Visual training
- 12 Vision restoration therapy
- 13 ''Saccades''/all subheadings
- 14 Eye movement and hemianop*
- 15 Oculomotor rehabilitation
- #16 #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15
- #17 #8 AND #16
- 18 Activity of daily living
- #19 #17 AND #18
- 21 Quality of life
- #22 #17 AND #21

Assessment of methodological quality of the trials

It is known that patients with visual deficits due to acquired brain damage are not a homogeneous group.[1 10] Because of the heterogeneity of underlying brain lesions, it is difficult to ensure that control and experimental groups are comparable.[1] RCTs are therefore scarce, and hence RMD studies were included, in which patients act as their own controls. All studies were scored on methodological quality. Two authors (LB and JH) independently assessed the publications with the Cochrane checklist for RCT and with the developed checklist for RMD studies (supplementary appendix 1 available online at http://jnnp.bmj.com/supplemental). Thirteen criteria were used to evaluate the internal validity and clinical relevance of RCT. Each criterion was scored as good, moderate or poor. A validated list of criteria for assessing the methodological quality of the RMD studies was not available, hence a list of 11 criteria was developed for assessing study quality (box 2).

Criteria were designed to tap domains of external validity (items 1–3) and internal validity (items 4–11). Three of the criteria described the external validity. The period of time after onset lesion, location of the lesion and aetiology of the lesion were considered important factors for external validity of the studies. Scores on items 4–11 were assumed to be of decisive importance for internal validity. Four outcome measures were included: size of visual field, size of visual search field (the term visual search field is defined as the area that a patient can actively scan by eye movements but without head movement), reading performance and subjective measures (items 4–7). Fixation control was defined as the criterion to assess whether the restitution of visual field was adequately measured. The aim of the VRT is to increase visual field size by shifting the absolute visual field border and improving detection ability in areas of residual vision. Stimulation in this area could provoke saccadic eye movements towards the stimulus, which can be misinterpreted as a visual field recovery.[14] Four confounding factors which could cause bias in the studies were analysed: stimuli of outcome measures derived from stimuli of the training programme or vice versa, comorbidities such as unilateral

Box 2 Criteria list for assessing the methodological quality of repeated-measures design studies

1. Was a representative sample of participants used?
2. Was the size of visual field defect sufficiently specified?
3. Was macular sparing/splitting specified in terms of measurement of macular sparing/splitting?
4. Was restitution of visual field adequately measured?
5. Was visual search field adequately measured?
6. Was reading performance adequately measured?
7. Was functional outcome adequately measured?
8. Were stimuli of outcome measures derived from the stimuli of the training programme or vice versa?
9. Was comorbidity identified as a confounding factor and controlled for?
10. Was spontaneous recovery identified as a confounding factor and controlled for?
11. Were examiners blinded to clinical information from participants?

spatial neglect, period of time after lesion onset and blinding of examiners (item 8–11). Items were scored as good, moderate or poor. Items were equally weighted.

Disagreements with respect to methodological quality were identified and resolved in a consensus discussion. If consensus could not be reached, the third reviewer (CL) made the final decision. The final quality score for each study was based on full consensus between the reviewers.

Data extraction and data analysis

From the original studies, we extracted data on participants (number, gender, age, time after onset, specification of visual field defect, aetiology and location of lesion), pathology from MRI/CT, confounding factors (comorbidity and spontaneous recovery), intervention (visual restoration therapy, compensation visual search therapy), outcome measures and transfer of treatment gains to functional outcome measures. The studies may not be sufficiently similar with respect to outcome measures to allow summarising data statistically. Hence, these studies are described here.

RESULTS

Literature search and study selection

The systematic literature search yielded 315 publications. Of these, 26 possible relevant studies were retrieved as full articles. As the review deals with a broad question, a sensitive search was performed in order not to miss possibly relevant studies. Consequently, 289 of the 315 publications did not meet the inclusion criteria. Of the 289 papers that were rejected, one third, for example, did not have the proper design as they were case studies. Furthermore, in the majority of the publications, hemianopia was only mentioned in the abstract or keywords as a sign of a particular disorder, and treatment was, as such, not the focus. This information could in all cases be retrieved from the abstracts.

Assessment of these studies with regard to their potential eligibility for meeting the entry criteria reduced the number of studies to 12. Reference tracing and hand searching yielded four more possibly relevant articles. In total, 14 studies were selected, of which 2 were RCT and 12 were RMD studies. There were 15 disagreements between reviewers on selection of the studies and extraction data, resulting in a moderate inter-reviewer agreement Cohen's κ of 0.54. All disagreements were resolved by discussion; consequently, there was no need to consult the third reviewer for a final decision.

Two RCT studies[4 5] and five RMD studies[6 7 8 12 13] described the effect of VRT. Seven studies with RMD[1 2 9–11 15 16] described the effect of SCT, of which two were focused on reading problems. A total of 420 patients who fulfilled the above-mentioned inclusion criteria were taken into account for this study. In all, 70 out of 420 subjects participated in the RCT (34 in the experimental group and 36 in the control group) and 350 in RMD studies; 64 patients were trained using the VRT and 286 patients using the SCT.

Assessment of methodological quality of the trials

Table 1 gives a detailed description of the included studies. The studies are listed according to the type of training and year of publication.

The agreement of the methodological quality assessment of the two authors (LB and JH) was high and after discussion full consensus was reached. Methodological quality scores of included studies are presented in table 2.

Of the studies that reported the effect of VRT, the RCT of Kasten *et al*[4] had good internal and external validity, but the follow-up study of Kasten *et al*[5] had poor internal validity. Of the RMD studies that reported the effect of the VRT, the study of Sabel *et al*[7] and Reinhard *et al*[13] had good internal validity. The study of Julkunen *et al*[6] had moderate internal validity. Two studies[8 12] had moderate to poor internal validity. Both studies were included in this systematic review because they contributed to the development of the rehabilitation of the patients with homonymous hemianopia. Balliet[12] was the first author to discuss the issue of an adequate fixation control, but did not have access to the developed instrumental measurements of the later studies. The study of Kasten *et al*[8] was an open pilot trial, which was followed in 1998 by the RCT study.[4] Five studies[4–8] reported a significant effect of VRT, whereas two studies[12 13] reported no effect of VRT.

Of the studies focused on SCT, the study of Kerkhoff *et al*[1 15] had good internal validity, whereas the study of Zihl[16] had moderate to good internal validity; the studies of Zihl,[2] Pambakian *et al*[10] and Kerkhoff *et al*[11] had moderate internal validity, and the study of Nelles *et al*[9] had poor internal validity. All authors found a significant effect of up to 30° visual search field, or a significant increase in reading speed or decrease in reading errors.

Data extraction and data analyses

Two RCT publications[4 5] were analysed. The first study[4] describes the pretreatment and post-treatment effects of restorative therapy, the second study[5] describes the follow-up. The RCT of Kasten *et al*[4] assessed in two independent trials the effect of VRT in patients with optic nerve lesion or post-chiasmatic brain injury. This review included only the trial of the post-chiasmatic lesions, which had a good methodological score on randomisation, blinding and comparability of the groups. Kasten found a border shift of 4.9° using high-resolution perimetry (HRP), but a border shift of 0.43° using Tuebinger automatic perimeter (TAP). In the follow-up study of Kasten *et al*,[5] the patients were recruited from the original population of the study of Kasten *et al*.[4] This study had poor internal validity, since the placebo group in the follow-up study was not blinded. All patients treated with placebo had been offered VRT after completion of the previous trial. Also, the number of patients treated with placebo was small.

Out of 10 patients in the placebo group, only 6 were re-examined. Different types of restoration therapy and outcome measures were used in comparison with the pretreatment and post-treatment periods.[4 5] Consequently, the outcome measures of the follow-up period were incomparable with the data before and after training.

Analysis of the RMD publications

All studies gave a good description of the characteristics of the population. Only Kasten *et al*[8] did not mention explicitly the inclusion and exclusion criteria. However, lesion location was specified in only two of the VRT studies[6 12] and in two of the compensatory therapy studies.[1 2] All other studies only described the lesions as post-chiasmatic and therefore, in many studies, it remained unclear to what extent the outcome was influenced by comorbidity. Two of the VRT studies[8 12] and two of the compensatory therapy studies[2 16] scored good on defining the size of the visual field defect. All other studies only described left or right, complete or incomplete HVFDs, and were therefore rated as moderate. Macular sparing/splitting was not mentioned in the majority of the compensation therapy studies,[1 9–11] whereas in the majority of the VRT studies the macular sparing/splitting was adequately measured.

Of the five VRT studies, restitution of the visual field was adequately measured in two studies.[7 13] The method used in these studies provides a simultaneous assessment of the retinal image and the stimulus in the central 10° visual field, thus allowing an absolute fixation control. Although all authors used the enlargement of the visual field as an outcome measure of the VRT, the instruments determining visual field were very

Table 1 Characteristics of included studies

Study	Method	Participants	Intervention	Outcome measures	Effect	Remarks
VRT						
Reinhard *et al* (2005)[13]	RMD study	17 patients, time after onset: >1 year, lesion location in central visual pathways	VRT: Nova Vision, 6 days a week, 60 min sessions, length of intervention 6 months	Objective	Objective	Pathology heterogeneous
	rm: 2	Mean age: 49 (range 24–72) years	Fixation control: no	SLO difference of ratio before and after training = E, 0.14E =1 degree	SLO: no increase in border shift	Outcome not comparable with other studies, no comparison between SLO and HRP/TAP
	Before training		Head and eye movements: no	ADL: text presented in the SLO, reading speed, wpm	ADL: reading speed: 6% improvement: not relevant	No correlation of objective results with subjective reports, no clear data
	After training				Subjective	Good internal validity
	No follow-up			Subjective	2/3 satisfied with training	
				Reports of patients	6 satisfied with reading; 4 not satisfied, 4 no reading problem before training	
Sabel *et al* (2004)[14]	RMD study	16 patients, post hoc 2 groups, COM (n=9) and INC (n=7), time after onset: >1 year, lesion location	VRT: Nova Vision, 6 days, twice a week, 30 min sessions, length of intervention 6 months	Objective	Objective	Pathology: heterogeneous
	rm: 2	Post-chiasmatic	Fixation control: no	SLO difference of ratio before after training=E, 0.14E=1 degree	SLO: no increase in border shift	Efficacy of VRT depends on which outcome measure is used
	Before training	Mean age: 49.3 (range 24–72) years	Head and eye movements: no	HRP, number of hits	HRP: 5.28–7.01° (0.20°) increase in border shift	Subjective: reading: no clear data
	After training			TAP, number of misses	HRP and TAP: OD 4.56–6.05° (0.20°); OS 4.49–5.47° (0.21°) increase in border shift	No relationship between improvement in perimetric procedures and subjective vision
	No follow-up			Subjective:		
				Standardised vision state questionnaire	Subjective:	Good internal validity
				Vision change questionnaire	87.5% satisfied with VRT	
				Reports of patients	Vision state questionnaire: 10% improvement	
					Vision change questionnaire: 14/15 patients improved	
Julkunen *et al* (2003)[6]	RMD study	5 patients, time after onset: >1 year, lesion location	VRT: developed computer program training, 3 times a week, 60 min sessions	Objective	Objective:	Pathology: homogeneous
	rm: 3	Left occipital inf 1	Length of intervention: 33–47 h (3–4 months)	Kinetic: Goldmann, degrees	Perimetry: yes, VEP: yes	Detailed description of patients
	Before training	Left occipital ich 1	Fixation control: yes	Static: Octopus101, degrees		No clear data of objective outcome measures and subjective data of reading
	After training	Right temporal ich 1	Head and eye movements: no	VEP, latency in ms	Subjective improvement 2, decline 2, no change 1	No general conclusions due to small group
	After follow-up	Left multiple ich 1		Subjective questionnaire		Moderate internal validity
	Follow-up period: 3 months	Right temperooccipital inf extending to thalamus:1				
		Age: 18–70 years				
Kasten *et al* (2001)[5]	Randomised trial double blind	22 patients, exp. group (n=16)	VRT: exp. group: Visure, Seetrain, plac. group: Fixtra, daily, 60 min sessions, length intervention 150 h within 6 months	Objective	Objective	Pathology: heterogeneous

Table 1 Continued

Study	Method	Participants	Intervention	Outcome measures	Effect	Remarks
	Follow-up study RCT 1998	Plac group (n = 6), time after onset: >1 year, lesion location	Fixation control: yes	PeriMa, number of stimuli; PeriForm, number of forms; PeriColor, number of colours; TAP, number of hits and misses	Mean (SD) exp.group increase 0.4 (0.9°), plac. group increase 0.13° (0.6°)	Different outcome measures and VRT in comparison with pretreatment and post-treatment periods (Kasten, 1998); hence incomparable with data before- and after training
	Follow-up period: Mean (SD) 23.5 (2.3) months	Post-chiasmatic-optic nerve Mean age Exp. group 47.7 (12.9), plac. group 55.3 (range 16.2)	Head and eye movements: no	Subjective Questionnaire	 Subjective From study 1998	No blinding of participants No subjective data from this study < poor internal validity >
Kasten *et al* (1998)[4]	Two randomised controlled trials 1. Optic nerve	46 patients Exp. group (n = 18)	VRT exp. group: Nova Vision, plac. group: fixation training programme, daily, 60 min sessions, length intervention 6 months.	Objective Primary: HRP,	Objective Primary: improvement	Pathology heterogeneous Subjective measures: no separate outcome measures optic nerve lesion and postchiasmatic
	2. Postchiasmatic included: postchiasmatic trial No follow-up	Plac. group (n = 30), time after onset: >1 year, lesion location Post-chiasmatic and Optic nerve Mean (SD) age Exp group 47.7 (12.9), plac. group 55.3 (16.2)	Fixation control; no Head and eye movements: no	Secondary: TAP Subjective Pre-trial: history interview Post-trial: questionnaire	Exp HRP: 29.4% border shift 4.9° (1.7), placebo HRP: 7.7% Border shift −0.9° (±0.8) Secondary: improvement Exp TAP border shift 0.43° (0.34) Placebo TAP −0.51° (0.34) Subjective improvements: Exp 72.2%, placebo: 16.6%	< good internal validity>
Kasten *et al* (1995)[8]	RMD study rm 2 Before training After training No follow-up	14 patients, time after onset: 0.5–240 months, lesion location: Post-chiasmatic. Mean age 48.5	VRT Visure, Seetrain, Formtrain, daily, 60 min sessions, length intervention 80–300 hours. Fixation control: no Head and eye movements: no	Objective Static perimetry: Perimat Periform Pericolor: Dynamic: TAP Subjective None	Objective Improvement: Perimat: 41.6% in 9 of 11 patients Periform: 37.4%, depending on hours of training Pericolor: 25.7% TAP: unclear	Pathology heterogeneous Specific training effect light, form and colour: modality specific Within first 20 hours no training effect, increase effect from 30 hours < moderate to poor internal validity>
Balliet *et al* (1985)[12]	RMD study rm 2 Before training After training No follow-up	12 patients, time after onset: 5–36 months, lesion location: Occipital. Age: 56–66	VRT Goldmann perimeter, compensation training for patients who failed VRT: Goldmann, 2–5 days weekly, 60 min sessions, length intervention 2–11 months. Fixation control: yes Head and eye movements: no	Objective Goldmann perimeter Subjective: Reports of patients	Objective: Restitution: Goldmann perimeter: 1° Compensation: 0° Subjective: report of patients: no changes in visual field	Pathology homogeneous Used same instrument for test and training (Goldmann), bias on training effect Emphasis on discussing measurement error caused by compensation eccentric fixation and on good fixation control < moderate to poor internal validity>
SCT Pambakian *et al* (2004)[10]	RMD study	31 patients, time after onset: 3 to >12 months, lesion location:	Compensation training	Objective	Objective	Pathology: heterogeneous

Table 1 Continued

Study	Method	Participants	Intervention	Outcome measures	Effect	Remarks
	rm 4	Postchiasmatic	Developed home training on a monitor, daily 40 min sessions, length intervention 1 month	Humphrey	Restitution: 0°	Used same instrument for test and training, bias on training effect
	2 before training	Mean age: 49.7 (range 24–75)		Response time, error rates	Compensation:76% improvement	Controlled for age: elderly patients benefited more from training
	2 after training Follow-up: 1 month			ADL: response time Subjective Standardised questionnaire Kerkhoff	ADL: 31 patients 25% improvement Subjective: Improvement of 27 patients S ($p = < 0.0002$)	< moderate internal validity >
Nelles *et al* (2001)[9]	RMD stduy	21 patients, mean time after onset:	VRT and compensation training on a board (CVFT), two daily, 30 min sessions, length intervention 1 month	Objective	Objective	Pathology: no description
	rm: 2	1. 5 months (range 0.5–24),		TAP	Restition: not mentioned	Outcome measure and intervention are alike: bias on training effect
	Before training After training follow-up period 8 months from 15 patients	no description lesion location. Mean age: 59.2 (±3.5) Subgroup A: eyes fixating B:exploratory eye movements		CVFT Reponse time, error rates Subjective Standardised questionnaire Kerkhoff with item reading added	Compensation: improvement Group A: NS Group B: S ($p \leqslant 0.02$) Subjective Improvement S($p \leqslant 0.05$)	Follow-up effect: no outcome measures <poor internal validity >
Zihl (1995)[2]	RMD study	14 patients, mean time after onset:	Compensation training	Objective	Objective:	Pathology: homogeneous
	rm 2	11 weeks (range 6–18), lesion location:	Saccadic eye movements with TAP, searching task with slides, 30 min sessions, length intervention 16 (range 8–23).	TAP	Restorative: no	Emphasis study oculomotor scanning
	Before training	Striate cortex, thalamus, occipito-parietal		Visual scanning: Pupil-corneal-reflection method, search time, length of scanpath,number of fixations.	Visual scanning: improvement three variables S ($p \leqslant 0.001$)	Damage in occipito-parietal cortex, optic radioation, striate cortex more training sessions necessary than occipital lesions
	After training No follow-up	Mean age: 44 (range 23–74)		Subjective Complaints before and after training	Subjective: reduction of complaints	No clear subjective measures <moderate internal validity >
Kerkhoff *et al* (1994)[1]	RMD study	22 patients, mean time after onset:	Compensation training	Objective:	Objective:	Pathology: homogeneous
	rm: 3	7.5 months (range 1–37), lesion location:	Training in 3 steps:	TAP	Restitution: mean increase	Left vs right hemianopia, early vs late training no significant differences
	Before training	occipital: 12	large saccades on large screen, visual search with slides, transfer to ADL,	Visual search field: TAP, slides, table test	6.6° (range 2° to 24°)	All patients returned to previous job
	After training	Occipito-temporal: 3	5 days a week, 30 min sessions, length intervention 1–3 months	Subjective	visual search field increase: mean 30°	<good internal validity >
	After follow-up	Temporal: 17		Standardised questionnaire Kerkhoff	search time decrease: S ($p = 0.01$), reduction of errors: 50%	
	Follow-up period: 3 months (1–12)	Mean age: 46 (range 16–77)			Subjective significant improvements p-value 0.01	
Kerkhoff *et al* (1992)[11]	RMD study	122 patients,	Compensation training	Objectieve	Objective:	Pathology: heterogeneous
	rm 3	VFD group ($n = 92$),	Training in 3 steps:	TAP	Restitution: mean increase: 1.6° (range 1.0° to 30°)	More training sessions necessary during training with head movements.

Table 1 Continued

Study	Method	Participants	Intervention	Outcome measures	Effect	Remarks
	Before training	VFD+ group ($n=30$),	Large saccades on large screen, visual search with slides, transfer to ADL		Visual search field increase: mean 30°	Time after lesion, etiology, type of visual field defect, visual field sparing and age irrelevant for treatment success
	After training	included VFD group,	5 days a week, 30	Subjective	Subjective	<moderate internal validity >
	After follow-up	mean time after onset: 32.8(range 1–220), lesion location	min sessions, length intervention 6 weeks	None	No data	
	Follow-up period: Mean 22 months	Postchiasmatic. Mean age 49 (range 117–74)				
SCT focused on reading						
Kerkhoff *et al* (1992)[15]	RMD study	56 patients, mean time after onset: 40.2 weeks (range 3–220), no description lesion location.	Compensation training	Objective	Restitution mean increase: 1.6° (range 1.0° to 20°)	Pathology: heterogeneous
	rm 3	Mean age: 46.8 (range 13–74)	Computer-based method with moving text, 5 days a week, 40 min sessions, length intervention 14 sessions in 4–6 weeks.	TAP	Reading time reduction:	Most severely disturbed patients benefited most during training
	Before training			Reading time	S ($p \leqslant 0.02$)	Reduction reading time irrespective initial reading time before training
	After training			Reading errors	Reading errors reduction:	<good internal validity >
	After follow-up			Subjective data	before treatment: 4.97 (8.1)	
	Follow-up period			Standardised questionnaire Kerkhoff	after follow-up: 1.48(1.66)	
	mean 22 months (6 months –5 years)				Subjective data not reported	
Zihl (1995)[16]	RMD study	20 patients,	Compensation training	Objective	Restitution: no	Pathology: heterogeneous
	rm: 2	LH group (n = 10)	Computer based with moving text, 5 days a week. 40 min sessions, mean length intervention LH 11 (range 8–16) sessions, RH 22 (range 9–29).	TAP	Reading speed: wpm	Clear relationship between improvements in reading performance and changes of eye movements parameters
	Before training	RH group (n = 10), time after onset:		Pupil-corneal reflection method	LH 76→113	< moderate to good internal validity >
	After training	LH 3–12 weeks (5.8), RH 4–9 weeks(5.9),			RH 53→96	
	No follow-up	No description lesion location. Mean age LH group 39 (range 21–53), RH group 37 (range 19–54)		Subjective data	Perceptual span	
				None	LH 3.75°→4.03° RH 2.79°→3.74° Subjective data None	

exp, experimental; HRP, High- resolution perimetry; Ich, intracerebral haemorrhage; Inf, infarction; LH, left-sided hemianopia; OD, right eye; OS, left eye; VRT, vision restoration therapy; VEP, Visual evoked potential; plac.,placebo; RCT, randomised controlled trial; RH, right-sided hemianopia; rm, repeated measures; RMD, repeated-measures design; S, significant; SLO, scanning laser ophthalmoscope; TAP, Tübinger automatic perimeter.

Table 2 Methodological quality scores of included studies of repeated-measures design (in alphabetical order on restoration and compensation therapy)

	External validity			Internal validity							
First author (year)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
VRT											
Balliet *et al* (1985)[12]	G	G	G	M	M	–	P	P	M	M	P
Kasten *et al* (1995)[8]	M	G	M	M	–	–	P	M	P	M	P
Julkunen *et al* (2003)[6]	G	M	P	M	–	–	M	G	M	G	P
Sabel *et al* (2004)[7]	G	M	M	G	–	–	G	G	M	G	P
Reinhard *et al* (2005)[13]	G	M	M	G	–	P	P	G	M	G	P
SCT											
Kerkhoff *et al* (1992)[11]	G	M	P	M	M	–	P	G	G	M	P
Kerkhoff *et al* (1994)[1]	G	M	P	M	G	–	G	G	G	M	P
Zihl (1995)[2]	G	G	M	M	M	–	M	G	M	M	P
Nelles *et al* (2001)[9]	G	M	P	–	M	–	G	P	P	P	P
Pambakian *et al* (2004)[10]	G	M	P	M	G	–	G	M	M	M	P
SCT focused on reading											
Kerkhoff *et al* (1992)[15]	G	M	G	M	–	G	P	G	G	M	P
Zihl (1995)[16]	G	G	G	–	–	M	P	G	G	M	P

–, not measured; G, good; M, moderate; P, poor.
Numbers correspond to questions in checklist for assessing methodological quality of subject within repeated-measures design.

diverse and made an overall effect estimate impossible. Sabel *et al*[7] found no effect on border shift using SLO, whereas he found an absolute border shift of 1.73° using HRP. Reinhard's *et al*'s study[13] used SLO and found no change in the absolute field defect border after training. Julkunen[6] used two perimetric methods and is the only author who applied pattern reversal visual evoked potential as an outcome measure. After training, there was a significant change of 5° in visual angle using the dynamic Goldmann perimeter and static Octopus101 perimeter. In 9 of the 11 patients Kasten *et al*[8] found a visual field enlargement using the Perimat test, with an average of 41.6%, and did not mention data regarding border shift of the visual field. No clear data were found using TAP. Balliet *et al*[12] found <1° of apparent visual field change using the dynamic Goldmann perimeter. In five SCT studies[1 2 10 11 15] the measurement of the restoration of visual field was not the focus of the study and was considered a byproduct of the visual training. These studies were defined as moderate. Zihl[2] and Pambakian *et al*[10] found no effect. Kerkhoff *et al*[1] found a mean increase of 6.6° (range 2° to 24°), Kerkhoff *et al*[15] a mean increase of 1.6° (range 1.0° to 20°) and Kerkhoff *et al*[11] a mean increase of 1.6° (range 1.0° to 30°). The clinical significance of the effect of an intervention depends on how large the treatment effects are in clinical practice. The VRT studies reported an effect of up to 5° increase in visual field size. This small effect could be clinically significant for reading, for fluent reading the visual span has to be extended up to 5°, whereas for scanning scenes this effect is too small to be clinically significant. An effect of up to 40° would be clinically significant enough for the subject to be able to explore the world as reported by the SCT studies.

Among the SCT studies, visual search field was adequately measured in the studies by Kerkhoff *et al*[1] and Pambakian *et al*,[10] since different methods for measuring VSF were used. The studies of Zihl,[2] Nelles *et al*[9] and Kerkhoff *et al*[11] were judged moderate using only one outcome measure. All studies showed an improvement in scanning strategies of up to 30° in the 46° VSF of the hemianopic visual field. As they used different instruments to measure the VSF, an overall effect estimate was not possible. Among the VRT studies, only the study of Balliet *et al*[12] trained and measured VSF as an effect on restitution. He found very small changes in VSF. The study was judged as moderate.

Kerkhoff *et al*[15] scored good on the retest reliability of the reading test. Zihl[16] used a standardised reading test and his study was judged moderate. In both studies, reading time and reading errors improved significantly. Of the VRT studies, only the study by Reinhard *et al*[13] measured the reading performance as the effect of VRT training. The study scored poor on the measurement of reading performance. The increase of 6% in reading performance after VRT is hence doubtful.

With regard to the subjective measures of improvement, a difference was found between restorative studies and compensatory studies. A total of four studies of compensatory therapy used validated or standardised questionnaires.[1 2 9 10] Only one study of restorative therapy[7] used a validated questionnaire.

In the studies by Balliet *et al*[12] and Nelles *et al*,[9] most of the stimuli that were used in training were also used in the evaluation of improvement, and therefore this criterion was judged as poor.

Only the studies of Kerkhoff *et al*[1 11 15] and Zihl[16] described the use of neuropsychological tests to exclude comorbidities such as visuospatial disorders, and visual agnosia and alexia as confounding factors.

Three recent VRT studies controlled for spontaneous recovery and only trained patients who were >1 year post-lesion.[6 7 13] In none of the RMD studies were the examiners blinded to clinical information from participants.

DISCUSSION

The methodological quality of the studies ranged from poor to good. Only two RCT studies could be selected from the literature search and therefore RMD studies were included in the search.

However, a repeated-measures design implicates less control, and internal validity is by definition lower compared with RCT studies. In order to assure internal validity of the RMD studies, it is necessary to ensure that no factors other than the intervention itself determine the outcome measure. Therefore, quality assessment was performed using a developed criteria list focused on the internal validity and in particular on information bias and confounding factors.

Strikingly, none of the RMD studies reported whether examiners were blinded to clinical information from participants. Hence we cannot exclude the possibility that examiners could have been influenced by the results of the training or by seeing previous perimetry results before each measurement. As a consequence, bias of outcome measures cannot be excluded. To resolve this issue, blinding of examiners should be pursued in future studies.

Only a few studies controlled for visual neglect and visual agnosia with neuropsychological tests.[1 11 15 16] Most studies did not pay much attention to the possibility of higher visual disorders. In our experience, cases of ''pure'' hemianopia are relatively rare because in most cases parts of the occipital pole (BA 17) as well as other, more anterior brain regions are damaged. The chances of higher order disorders supplementary to the hemianopia are quite high when the occipitotemporal or occipitoparietal regions are involved. Since in most studies patients were selected on the basis of having post-chiasmatic lesions, it is unlikely that lesions of these patients were limited to the occipital pole.

The size of the visual field defect and the presence or absence of macular sparing or splitting depends on the location of the brain lesion and varies between patients. In general, macular sparing in hemianopia occurs only when the lesion is limited to the occipital pole. Hence, it should be analysed carefully and expressed in the outcome measures. The majority of the studies did not specify these factors, which might be of importance for the chances of successful rehabilitation. Except for the studies of Kerkhoff *et al*[1] post hoc, Kasten *et al*[5] and Sabel *et al*,[7] in none of the studies was the size of the HVFD taken into account as a weighed measure in the analysis of improvement after treatment.

Among the five studies that met the entry criteria of the restoration intervention, a certain line of research can be distinguished starting from the study of Balliet *et al*[12] to the recent study of Reinhard.[13] Zihl and Von Cramon were the first to evaluate systematically the effects of specific perimetry training on visual field size in visual field defects.[17] Since the 1980s, there has been considerable development in the quality of methods and instruments to assess visual fields and fixation control. Our review shows no consensus between different authors about which methods should be used to measure the exact size of the visual field and improvements in the transition zone. Some authors[12 13] claim that studies using perimetric or campimetric methods do not control sufficiently for eye movements or para-central fixation. There is a discussion about a mismatch of border position between SLO on the one hand and HRP/TAP on the other hand. In most patients the SLO is noticeably closer to the midline than the HRP/TAP border.[7] In all studies, the original size of the visual field defect and also the efficacy of VRT depended on the method of the perimetric measurements and on the fixation control that was used. Thus, the apparent visual field defect is greater when measured with SLO than when measured with HRP or TAP. After VRT, the mismatch is even more pronounced. To our knowledge, this matter has not been resolved.

Potential confounders are the effect of practice in detection or discrimination tasks, and measurement errors due to improper fixation, which can cause eccentric fixation. Improper alignment in the baseline measurement can cause a mismatch border position.

It would have been very useful to evaluate whether an improvement in the transition zone also leads to an improvement in the VSF. We found no strong evidence that the possible gain of a few degrees of visual field results in better oculomotor scanning strategies and leads to a better performance of activities of daily living.

If visual search field and relevant activities of daily living such as reading would indeed improve as a result of a small border shift, one would perhaps also expect that the initial size of the VFD before the training would correlate to the level of impairment. To our knowledge, there is no strong evidence that points to this. On the other hand, it seems that in VRT studies there is a basic assumption that patients benifit from reducing the HVFD by a few degrees, which makes it even more necessary to use the size of the initial visual field deficit as a weighed factor in the analysis.

SCT seems to provide a more successful rehabilitation, with more simple and user-friendly training techniques. The data of the studies show that patients performed significantly faster in search strategies after compensatory therapy. Scanning strategies are applied to and trained in real life scenes. However, none of these studies compare the results with those of an untreated control group.

The evidence of the transfer of training-related improvements in activities of daily living of both VRT and SCT is limited. Validated questionnaires seem to provide the most reliable subjective data to assess the translation of the relevance of training procedures to activities of daily living of the patient.

CONCLUSION

It is unclear to what extent patients benefit from restoration therapy in relation to a more efficient scanning strategy that enables them to read faster or to avoid obstacles in a better way.

No study has given a satisfactory answer. The discrepancy between the positive results of the restoration by perimetric measurements and the null-SLO finding diminishes the chances of restoration after VRT. The latest discussions prove that restorative therapy requires further study of residual vision.

Transfer of visual search performance in activities of daily living is not sufficiently proven. There is a need for more validated instruments that can measure therapy outcome objectively.

Until the effect of the restoration therapy is further evaluated, visual search therapy is recommended.

ACKNOWLEDGEMENTS

We thank Professor Dr J Zihl for his comments and advise as an expert in the field. We also thank Jos W Snoek, MD, PhD, neurologist, Anja van de Wege, PhD, Marion Priebe, MSc, and Emiel van Trijffel, MSc, for critically reviewing the draft version of this paper.

Supplementary file containing the appendix is available online at http://jnnp.bmj.com/supplemental

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Competing interests: None declared.

REFERENCES

1 **Kerkhoff G**, Munssinger U, Meier K. Neurovisual rehabilitation in cerebral blindness. *Arch Neurol* 1994;**51**:474–81.
2 **Zihl J**. Visual scanning behavior in patients with homonymous hemianopia. *Neuropsychologia* 1995;**33**:287–303.
3 **Poppelreuter W**. *Disturbances of lower and higher visual capacities caused by occipital damage*. Zihl J, Weiskrantz L. (Translators). Oxford: Clarendon Press, 1917/1990.
4 **Kasten E**, Wuest S, Behrens-Baumann W, *et al*. Computer-based training for the treatment of partial blindness. *Nat Med* 1998;**4**:1083–7.
5 **Kasten E**, Muller-Oehring E, Sabel BA. Stability of visual field enlargements following computer-based restitution training-results of a follow-up. *J Clin Exp Neuropsychol* 2001;**3**:297–305.
6 **Julkunen L**, Tenovuo O, Jaaskelainen S, *et al*. Computer-assisted training: a clinical and neurophysiological study. *Restor Neurol Neurosci* 2000;**21**:19–28.

7 **Sabel BA**, Kenkel S, Kasten E. Vision restoration therapy (VRT) efficacy as assessed by comparative perimetric analysis and subjective questionnaires. *Restor Neurol Neurosci* 2004;**22**:399–420.
8 **Kasten E**, Sabel BA. Visual field enlargement after computer training in brain-damaged patients with homonymous deficits. *Restor Neurol Neurosci* 1995;**8**:113–27.
9 **Nelles G**, Esser J, Eckstein A, *et al*. Compensatory visual field training for patients with hemianopia after stroke. *Neurosci Lett* 2001;**306**:189–92.
10 **Pambakian AL**, Mannan SK, Hodgson TL, *et al*. Saccadic visual search training: a treatment for patients with homonymous hemianopia. *J Neurol Neurosurg Psychiatry* 2004;**75**:1443–8.
11 **Kerkhoff G**, Munssinger U, Haaf E, *et al*. Rehabilitation of homonymous scotomata in patients with postgeniculate damage of the visual system: Saccadic compensation training. *Restor Neurol Neurosci* 1992;**4**:245–54.
12 **Balliet R**, Blood KM, Bach-y-Rita P. Visual field rehabilitation in the cortically blind? *J Neurol Neurosurg Psychiatry* 1985;**48**:1113–24.
13 **Reinhard J**, Schreiber A, Schiefer U, *et al*. Does visual restitution training change absolute homonymous visual field defects? A fundus controlled study. *Br J Ophthalmol* 2005;**89**:30–5.
14 **Sabel BA**, Trauzettel-Klosinski S. Improving vision in a patient with homonymous hemianopia. *J Neuro-Ophthalmol* 2005;**25**:143–9.
15 **Kerkhoff G**, Munssinger U, Eberle-Strauss G, *et al*. Rehabilitation of hemianopic alexia in patients with postgeniculate visual field disorders. *Neuropsychol Rehabil* 1992;**2**:21–42.
16 **Zihl J**. Eye movement patterns in hemianopic dyslexia. *Brain* 1995;**118**:891–912.
17 **Zihl J**, Von Cramon D. Visual field recovery from scotoma in patients with postgeniculate damage. *Brain* 1985;**108**:335–65.

NEUROLOGICAL PICTURE

doi: 10.1136/jnnp.2006.105593

Carotid embolism

A 56-year-old woman presented with fluctuating left-sided hemiparesis. The initial computer tomography scan showed signs of a frontal cortical ischaemia within the territory of the prerolandic artery. Duplex sonography showed a pulsating structure within the right internal carotid artery. An angiographic investigation showed a large polymorphic thrombus within the internal carotid artery (fig 1). Atrial fibrillation was detected in the electrocardiogram. The echocardiogram showed dilation of the left atrium. The heart valves were intact and no cardiac thrombi could be found.

Before a thrombectomy could be performed, the carotid artery became desobliterated spontaneously and further ischaemic lesions developed in the territories of the right arteria cerebri media and arteria cerebri anterior.

Absolute arrhythmia is the most common cause of cerebral thromboembolism.[1] The intracerebral arteries are usually affected.[2] In contrast, the finding of a large thrombus in the carotid artery as in the present case is very rare.[3]

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Competing interests: None declared.

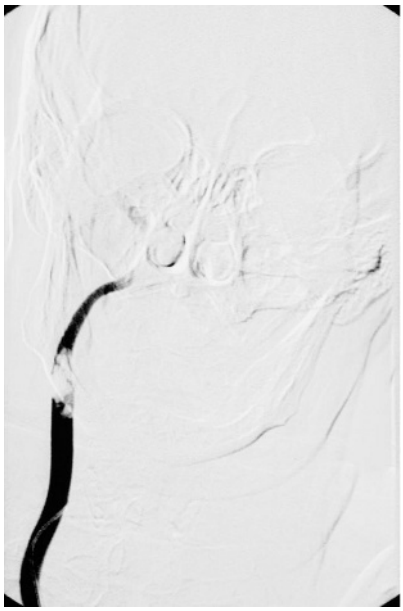

Figure 1 Angiography image showing large polymorphic thrombus within the internal carotid artery.

References

1 **Berlit P**. Cardiac cerebral embolism. *Nervenarzt* 1983;**54**:389–99.
2 **Ueda S**, Fujitsu K, Inomori S, *et al*. Thrombotic occlusion of the middle cerebral artery. *Stroke* 1992;**23**:1761–6.
3 **Kimura K**, Yasaka M, Minematsu K, *et al*. Oscillating thromboemboli within the extracranial internal carotid artery demonstrated by ultrasonography in patients with acute cardioembolic stroke. *Ultrasound Med Biol* 1998;**24**:1121–4.