NovaVision Clinical Research on Vision Restoration Therapy (VRT) and NeuroEyeCoach

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Research Supporting Vision Restoration Therapy (VRT™)

VRT has been supported by 15 years of research with clinical studies published in more than 30 leading journals

Romano JG, Schulz P, Kenkel S, Todd DP (2008). Visual field changes after a rehabilitation intervention: Vision Restoration Therapy. **Journal of the Neurological Sciences**; 132: 70-74

Objective of this retrospective study was to determine the effect of Vision Restoration Therapy VRT on visual field defects in a US cohort. The study evaluated 161 Patients with postchiasmatic lesions who performed 6 modules of VRT with suprathreshold central visual field testing at baseline and after each module. Outcome measures were change in stimulus detection and border shift. Results: mean absolute improvement in stimuli detection was 12.8 %. Improvements of > 3 % was noted in 76 % of patients. The average border shift was 4.87 %. Patient age, time from lesion and type of visual field defect did not influence the degree of field expansion. Conclusions: VRT improves stimulus detection and results in a shift of the position of the border of the blind field as measured on suprathreshold visual field testing. These results support prior reports and support VRT as a useful rehabilitative intervention.

Plow EB, Obretenova SN, Fregni F, Pascual-Leone A, Merabet LB (2012). Comparison of Visual Field Training for Hemianopia With Active Versus Sham Transcranial Direct Cortical Stimulation. **Neurorehabilitation and Neural Repair**; 20 (10): 1–11

Vision Restoration Therapy (VRT) aims to improve visual field function by systematically training regions of residual vision associated with the activity of suboptimal firing neurons within the occipital cortex. Transcranial direct current stimulation (tDCS) has been shown to modulate cortical excitability. This study was performed to assess the possible efficacy of tDCS combined with VRT. The authors conducted a randomized, double-blind, demonstration-of-concept pilot study where participants were assigned to either VRT and tDCS or VRT and sham. Outcome measures included objective and subjective changes in visual field, recording of visual fixation performance, and vision-related activities of daily living (ADLs) and quality of life (QOL). The VRT and tDCS group demonstrated significantly greater expansion in visual field and improvement on ADLs compared with the VRT and sham group. The combination of occipital cortical tDCS with visual field rehabilitation appears to enhance visual functional outcomes compared with visual rehabilitation alone. TDCS may enhance inherent mechanisms of plasticity associated with training.

Marshall RS, Ferrera JJ, Barnes A, Zhang X, O'Brien KA, Chmayssani M, Hirsch J, Lazar RM (2007). Brain activity associated with stimulation therapy of the visual borderzone in hemianopic stroke patients. **Neurorehabilitation and Neural Repair**; 22(2): 136-144

Study objective was to examine whether VRT would induce visual field location-specific changes in the brain's response to stimuli. Six chronic right hemianopic patients underwent fMRI – responding to stimuli in the trained visual borderzone versus the non-trained seeing field before and after 1 month of VRT. Percent change in Blood oxygen level dependent (BOLD) activity was compared between conditions. Results: BOLD activity at the borderzone was significantly increased after one month of training as compared to activity in the seeing field. Greatest response was shown in right inferior and lateral temporal, right dorsolateral frontal, bilateral anterior cingulate and bilateral basal ganglia region. Conclusion: VRT appears to induce an alteration in brain activity associated with a shift of attention from the non-trained seeing field to the trained borderzone. The effect appears to be mediated by the anterior cingulate and dorsolateral frontal cortex in conjunction with other higher order visual areas in the occipitotemporal and middle temporal regions.

Kasten E, Wuest S, Behrens-Baumann W, Sabel BA (1998). Computer-based training for the treatment of partial blindness. **Nature Medicine**; 4 (9): 1083-1087

Partial blindness in the form of a visual field defect (VFD) after brain injury has long been considered non-treatable. A prospective double-blind placebo-controlled study was performed to evaluate the treatment outcome of computer-based Vision Restoration Therapy (VRT) on patients with VFD after a post-chiasmatic brain injury (n= 19) or after optic nerve injury (n=19). VRT was performed twice a day for about six months. VRT led to a significant 29.4 % improvement in stimulus detection over baseline in patients with post-chiasmatic lesions, and a 73.6 % improvement in patients with optic nerve lesions. An average visual field enlargement of 4.9 / 5.8 degrees of visual angle was found in computer-based suprathreshold central visual field testing. 72 % of patients reported subjective visual improvements in their daily life. Patients receiving a placebo treatment did not show comparable improvements. In conclusion, VRT has proven to significantly improve visual functions of patients with visual field defects due to post-chiasmatic or optic nerve lesions.

***Complete articles are available online at www.sightscience.com**

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Mueller I, Poggel DA, Kenkel S, Kasten E, Sabel BA (2003). Vision Restoration Therapy (VRT) after brain damage: subjective improvements of activities of daily life and their relationship to visual field enlargements. **Visual Impairment Research**; 5 (3): 157-178

Study objective was to determine whether VRT-induced visual field enlargements are relevant to visually guided activities of daily life (ADL). A retrospective analysis of 69 patients who were interviewed after performing 6 modules of VRT was carried out. Patient testimonial statements were categorized posthoc and were correlated with demographic status and pre/post VRT changes. Results: stimulus detection ability was significantly increased after VRT, 88 % of patients report subjective benefits in ADL. Significant correlation was found in the categories "carrying out hobbies" and "general improvement of vision". A trend was evident for "reading". The categories "visual confidence/-mobility" and "ability to avoid collisions" did not correlate with size of visual field improvements. Thus, visual field size appears only to be one, surprisingly minor, factor among others to determine subjective vision in brain damaged patients.

Poggel DA, Kasten E, Sabel BA (2004). Attentional cueing improves vision restoration therapy in patients with visual field defects". **Neurology**; 63: 2069-2076

Objective of this study was to examine whether directing attention to defined areas with residual vision at the visual field border by using a visuospatial cue increases long-term neural plasticity and enhances permanent training outcome. In a prospective, randomized clinical trial, VRT treatment outcome was compared in patients with postgeniculate lesions receiving either standard VRT (control group, n=10) or VRT with attentional cueing (experimental group, n=9). Visual field size was determined before and after a 6-month-treatment period with standard perimetry and suprathreshold visual field testing. Results: Overall, subjects displayed a significant average stimulus detection improvement after VRT. In the area utilizing a cue for VRT, stimulus detection was better than in areas without a cue or in the control group. Focusing attention at an area with residual vision changed topographic and temporal patterns of recovery. Authors propose that top-down signals preactivate partially damaged areas of V1, thus linking visual and attentional neuronal networks with the effect of better therapy outcome.

Poggel DA, Mueller-Oehring EM, Kasten E, Bunzenthal U, Sabel BA (2007). The topography of training induced visual field recovery: Perimetric maps and subjective representations. **Visual Cognition**; 16 (8): 1059-1077

The cognitive representation of blind regions varies considerably between patients with vision loss and may influence compensatory behavior and treatment motivation. We measured "objective" visual field topography (perimetry) in 19 patients with postgeniculate lesions and related this to the subjective scotoma representation as expressed by patients' drawings of the defect. We monitored changes during VRT-induced recovery of function. Blind regions were mostly adequately represented; however, central regions were overestimated and peripheral areas underestimated in size. Perimetric and subjective defect size decreased significantly during training. Again, central visual field border shifts were larger in subjective than in perimetric maps but vice versa in the peripheral field. Thus, VRT improves "objective" visual field size along with its cognitive representation. Subjective topography is shaped by the functional importance of visual field regions, thus resembling neural representation in visual cortex (cortical magnification).

Gall C, Mueller I, Gudlin J, Lindig A, Schlueter D, Jobke S, Franke GH, Sabel BA (2008). Vision and health-related quality of life before and after vision restoration training in cerebrally damaged patients. **Restorative Neurology and Neuroscience**; 26: 341-353

Aim of the study was to examine whether VRT-related improvements in stimulus detection of patients with VFD are associated with changes in self-reported vision-and health-related quality of life (QoL). 85 patients with VFD after brain damage underwent VRT for overall 75 or 150 hours. Stimulus detection was quantified pre and post VRT with suprathreshold central visual field testing. QoL was assessed by the Health-Survey SF-36 and the 39-item National Eye Institute Visual Functional Questionnaire NEI-VFQ. Results: both vision- and health-related QoL measures improved after VRT. Significant increases were found in 8 out of 12 subscales of the NEI-VFQ, and in 3 out of 8 subscales of the SF-36. Changes in stimulus detection were related to changes in the subscale ratings "general vision", "difficulty with near vision activities", "limitations in social functioning" and "driving" of the NEI-VFQ. In conclusion, visual field enlargements after VRT were related to improvements in vision-related Quality of Life of patients.

***Complete articles are available online at www.sightscience.com**

NeuroEyeCoach™ is the first commercially available eye movement-training program which is underpinned by a number of clinical and scientific studies. The program is specifically targeted at improving visual search efficiency in patients with visual field loss after brain injury. The underlying impact that has been established through extensive research is a significant improvement in the patient's visual performance leading to a better quality of life. Below are selected summaries of published literature that support the use of this technique.

Zihl J (1995). Visual scanning behaviour in patients with homonymous hemianopia. Neuropsychologia; 33: 287-303.

This study examined oculomotor scanning behavior in 60 patients suffering from homonymous hemianopia due to postgeniculate damage. Eye movements were recorded using an infra-red recording technique during performance of a visual searching task. In 24 patients (40%) scanning behavior was found to be normal; the remaining 60% showed significantly increased search times. Detailed analysis of patients' eye movements revealed that the pronounced slowing of visual scanning was mainly due to the disordered spatial organization of scanning not only in the affected, but also, to a lesser degree, in the intact hemifield. CT and NMR examination revealed that additional damage to the ipsilateral occipital white matter, posterior thalamus or the parieto-occipital cortex results in impaired spatial organization of visual scanning. A smaller group of patients (n = 14) with impaired visual scanning was treated to improve the spatial organization of visual exploration. After training, all patients showed a significant improvement in visual searching.

Conclusion
Study shows that successful oculomotor adaptation can substitute the lost visual hemifield. The reason behind its effectiveness is based on the findings that impaired visual scanning in hemianopic patients is mainly caused by visual spatial disorientation that also affects spatial integration of visual information.

Schuett S, Zihl J (2013). Does age matter? Age and rehabilitation of visual field disorders after brain injury. Cortex; 49: 1001-1012

Traditionally, it has been assumed that younger patients with brain injury are more likely to recover than the older adults. In this study Schuett & Zihl recruited 38 patients with homonymous visual field defects (HVFD). Patients undertook eye movement training as well as a reading therapy. The main finding was that older patients (mean: 77 years, range: 70-84 years) achieved the same treatment-induced improvements in reading and visual exploration with the same amount of treatment as younger patients (mean: 28 years, range: 20-35 years); severity of functional impairment also did not differ between older and younger patients, at least in reading.

Conclusion
Age does not seem to be a critical factor determining the functional and rehabilitation outcome in the compensatory treatment of HVFD. Older age per se is not necessarily associated with a decline in practice-dependent functional plasticity and adaptation. To the contrary, the effectiveness of compensatory treatment to reduce the functional impairments to a similar extent in younger and older patients with HVFD adds to the growing evidence for a life-long potential for adaptation to the adverse visual effects of brain injury.

Schuett S, Heywood CA, Kentridge RW, Dauner R, Zihl J (2012). Rehabilitation of reading and visual exploration in visual field disorders: transfer or specificity. Brain; 135: 912-921.

Compensatory therapies are aimed at improving eye movement and visual search efficiency after brain injury leading to unilateral homonymous visual field defects. These interventions allow patients to regain sufficient reading and visual exploration performance through systematic oculomotor training. In a cross-over rehabilitation study, the authors investigated whether the training-related performance improvements are task specific or whether there is a transfer of training related improvements between reading and visual exploration. They compared the therapeutic effects of compensatory oculomotor reading and saccadic eye movement training in 36 patients. In addition they investigated whether the training sequence determined the overall treatment outcome.

Conclusion
The findings demonstrated that the training-related improvements in reading and visual exploration were highly specific and task dependant and there was no effect of training sequence.

Aimola L, Lane AR, Smith DT, Kerkhoff G, Ford GA, Schenk T (2014). Efficacy and feasibility of home-based training for individuals with homonymous visual field defects. Neurorehabilitation and Neural Repair; 28: 207-218.

Authors have randomly allocated 70 patients into intervention and control groups. The intervention group undertook both a computer based visual search task as well as a reading task for 35 one hourly sessions. The control group undertook a fixation task of similar duration and attentional demand. Eighteen individuals failed to complete the training, but 28 in the intervention group and 24 controls completed the training. Individuals in the intervention group demonstrated significant improvements in the primary outcomes of saccadic exploration and reading which were significantly greater than those observed following the control intervention.

Conclusion
In conclusion, home-based compensatory training is an inexpensive accessible rehabilitation option for individuals with homonymous visual field defects, which can result in objective benefits in searching and reading, as well as improving quality of life.

Mannan SK, Pambakian ALM, Kennard C (2010). Compensatory strategies following visual search training in patients with homonymous hemianopia: an eye movement study. Journal of Neurology; 257: 1812-1821.

Using a visual search task, patients explored a computer screen, searching for a single randomly positioned target amongst distractors. 29 patients with homonymous visual field defect completed the 20 daily sessions over a period of 4 weeks. After training, patients demonstrated significantly shorter reaction times for search stimuli. Patients achieved improved search efficiency after training by altering their oculomotor behaviour in the following ways: (1) patients directed a higher proportion of fixations into the hemispace containing the target, (2) patients were quicker to saccade into the hemifield containing the target if the initial saccade had been made into the opposite hemifield, (3) patients made fewer transitions from one hemifield to another before locating the target, (4) patients made a larger initial saccade, although the direction of the initial saccade did not change as a result of training, (5) patients acquired a larger visual lobe in their blind hemifield after training. Patients also required fewer saccades to locate the target after training reflecting improved search efficiency. All these changes were maintained at follow-up one month after the completion of training.

Conclusion
Taken together these results suggest that computer based visual training facilitates the development of specific compensatory eye movement strategies in patients with homonymous visual field defects.

Kerkhoff G, Münßinger U, Haff E, Eberle-Strauss G, Stögerer E (1992). Rehabilitation of homonymous scotomata in patients with postgeniculate damage of the visual system: saccadic compensation training. Restorative Neurology and Neuroscience; 4: 245-254.

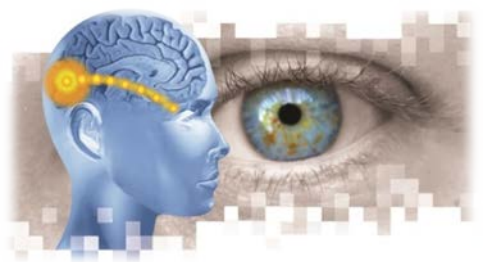
A systematic training procedure for patients with disturbed visual search was evaluated in 92 patients with postchiasmatic visual field disorders (VFD) and 30 VFD patients with additional left sided visual neglect (VFD +). Visual fields and areas of visual search via saccadic eye movements in the scotomatous field (search field) were mapped perimetrically in all patients before and after training and after a follow-up interval (mean follow-up interval: 22 months).

Conclusion
A significant increase of more than 20° of visual angle was found in visual search field in the scotomatous field during training. Search field remained stable at follow-up in both patient groups. In contrast, only minor, though significant increases in visual field size were obtained during search field training in some patients. Multiple baseline designs in 5 patients revealed that search field enlargements were training dependent and not related to spontaneous recovery, adaptation to test procedures or measurement variability.

Pambakian ALM, Mannan SK, Hodgson TL, Kennard C (2004). Saccadic visual search training: a treatment for patients with homonymous hemianopia. Journal of Neurology, Neurosurgery and Psychiatry; 75: 1443-1448.

Authors describe how the completion of 20 daily sessions of visual search task could lead to improved eye movement efficiency. They hypothesised that the improvement gained in training , would lead to reduction of patients' disability. Improvements were assessed by examining response time (RT), error rates in visual search, perimetric visual fields and visual search fields, before and after the intervention in patients with homonymous visual field defect (n=29). As a group the patients had significantly shorter mean RT in visual search after training. Improvements were confined to the training period and maintained at follow up. Three patients had significantly longer RT after training. They had high initial error rates which improved with training. Patients performed Activities of Daily Living (ADL) tasks significantly faster after training and reported significant subjective improvements.

Conclusion
Patients can improve in visual search with practice. This usually involves shorter RTs, but occasionally a longer RT in a complex speed–accuracy trade-off. These changes translate to improved overall visual function, assessed objectively and subjectively, suggesting that they represent robust training effects.



NEUROEYECOACH OCT 2016 STUDY

Clinical Study Supports NeuroEyeCoach as The Gold Standard for Neurological Vision Therapy

A new rigorous peer-reviewed study published in *BioMed Research International* Oct 2016 shows improvements in visual search following the use of NovaVision's NeuroEyeCoach. The three-centre study was conducted by the School of Psychology of University of Aberdeen, the Neuromotor and Cognitive Rehabilitation Research Centre of University of Verona, and the Department of Psychology of University of Munich.

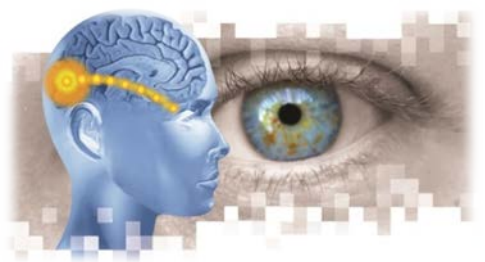
"This type of sight deficit can be massively debilitating for those affected by it", said Professor Arash Sahraie, head of the school of psychology at the University of Aberdeen who led the study. "Patients report a loss of confidence in their own ability to navigate the environment that can then manifest itself in the form of withdrawal from daily life. This is why it's important to develop techniques to help patients to improve as much as they can and this compensatory technique is yet another step forward in providing help and therapy for these patients."

The study concludes "NeuroEyeCoach can be used as an effective rehabilitation tool to develop compensatory strategies in patients with visual field deficits after brain injury" and that NeuroEyeCoach can be viewed as being the first evidence-based, vision-specific, clinical gold standard registered medical device accessible to patients at home or in clinical settings.

Background:
Many patients who have a visual field deficit after suffering a stroke or brain injury also have difficulties with eye movements. They are less efficient at processing their visual field, moving their eyes around less, exploring more of the region they can see rather than trying to explore the "blind areas", and are less able to integrate information between the left and right hand side of their vision. Therefore, they have less awareness of things happening at the side of their visual field and are not able to grasp a scene as a whole, and as a result bump into objects or perceive a problem with their peripheral vision

Only about 20% of people are able to recover without clinical intervention. The use of visual search in improving the search efficiency of hemianopic patients was first reported in 1988. Other than its use in a limited number of research environments or rehabilitation clinics over the past 25 years, there has been a marked lack of an evidence-based, vision-specific medical device broadly accessible to patients, despite there being a large body of evidence including randomized control trials showing that patients benefit from systematic eye movement training.

Therapists and physicians in clinical practice have instead used a number of devices that originally had been designed to address other problems; these do not have a set of systematically developed protocols specific to visually impaired patients and are therefore sub-optimum for their rehabilitation.



NEUROEYECOACH OCT 2016 STUDY

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The Key Study Findings

Three distinct **observational studies** were performed as part of the overall study:

1. The first objective was to confirm that NeuroEyeCoach did indeed provide at least as positive outcomes as the large body of clinical evidence upon which the program was based. The use of computerized visual search tasks as a rehabilitation tool to improve eye movements after brain injury had previously been used in 13 studies with a total of 551 patients with homonymous visual field loss and persistent visual disabilities. Each of the studies focused on different aspects however, in aggregate, the outcome of the studies demonstrated a significant improvement in visual search performance accompanied by more efficient oculomotor strategies and a reduction in visual disability as assessed with standard questionnaires and behavioural measures.

The first study concluded that patients showed similar improvements to prior studies with regard to visual search and reported functioning in daily life activities **with the added advantage of having set criteria for progression to different levels of difficulty**,

2. The second objective was to find out whether the program-inbuilt, self-administered outcome measures can be used to assess patients' NeuroEyeCoach therapy outcomes, whether this additional cohort of patients benefitted from visual search training and whether changes are measurable using the incorporated pre- and post-assessments.

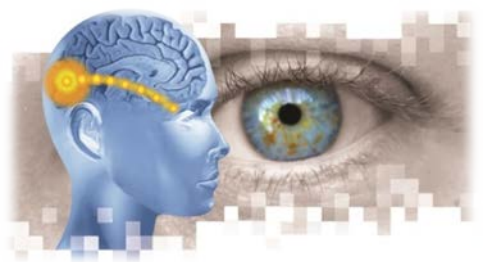
The second study concluded that this cohort of patients also benefited from eye movement training and that this benefit could be assessed effectively using the program's inbuilt outcome measures. **The training led to faster visual search times, reduction in the number of errors made, and improvements in self-reported activities of daily living.**

3. The third study focused on the comparison of changes in visual search in a group of patients with those of a similarly-aged control group of healthy subjects ("normal controls"), with both groups conducting the therapy under supervision at clinical rehab units.

The findings from this final study showed that the use of NeuroEyeCoach in patients can lead to more than **TWICE the magnitude of improvements** compared to normal controls. This evidenced that patients suffering from homonymous visual field benefitted far beyond simple program familiarity, but regained an effective scanning strategy to substitute for the lost visual field, which the study highlights as being a **crucial prerequisite for grasping the actual surroundings with high accuracy and speed.**

Conclusion

"NeuroEyeCoach is an effective compensatory approach for those with homonymous visual field loss. The training led to faster visual search times, reduction in the number of errors made, and improvements in reported activities of daily living"



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"It's important to develop techniques to help patients to compensate for their sight deficits and NeuroEyeCoach is providing a much needed step forward in providing therapy for these patients in order to improve the quality of life for the individual. We have used this type of compensatory technique in vision research for some time now and in NeuroEyeCoach, we have developed the research into an accessible treatment that can help patients achieve major improvements in their vision within about 2-3 weeks."

- Professor Arash Sahraie, Head of the School of Psychology, University of Aberdeen

Link to the study: https://www.hindawi.com/journals/bmri/2016/5186461/

NeuroEyeCoach Program Description

NeuroEyeCoach was developed to address this need and provide a standardized protocol for clinical management of patients using a compensatory technique. The program systematically increases the task difficulty from a simple "pop-out" search, to more complex search with multiple distractors, and finally conjunction searches where distractor number and target/distractor similarity are manipulated. The program has been designed to be highly intuitive, using simple on-screen and audio instructions, and automatically adjusting to the patient's ability and progress. This ensures that this therapy is appropriate for use unsupervised at home as well as under supervision in clinical settings.