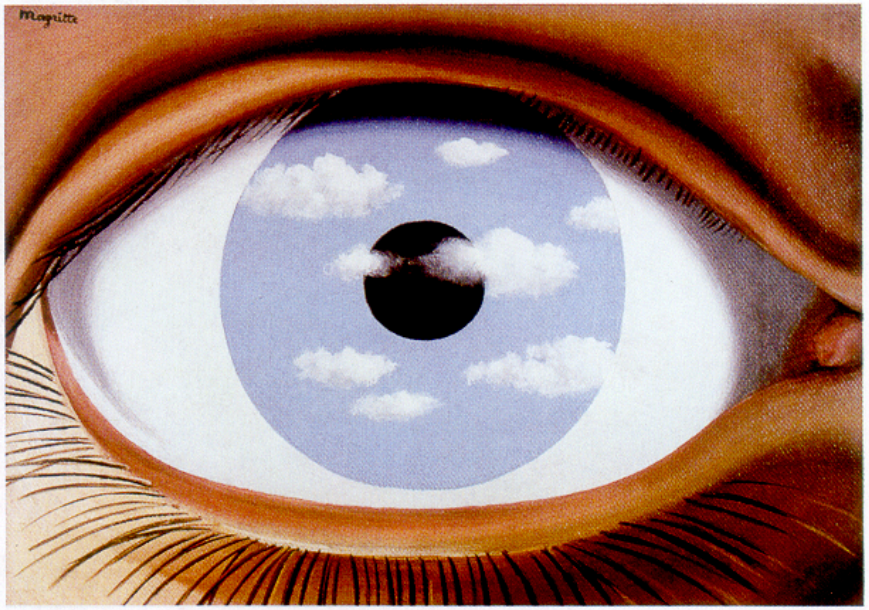
Rehabilitation of the damaged visual brain



Christopher Kennard

Nuffield Department of Clinical Neurosciences

University of Oxford

Hemianaopia and neglect – new concepts and therapies

Plan

General introduction

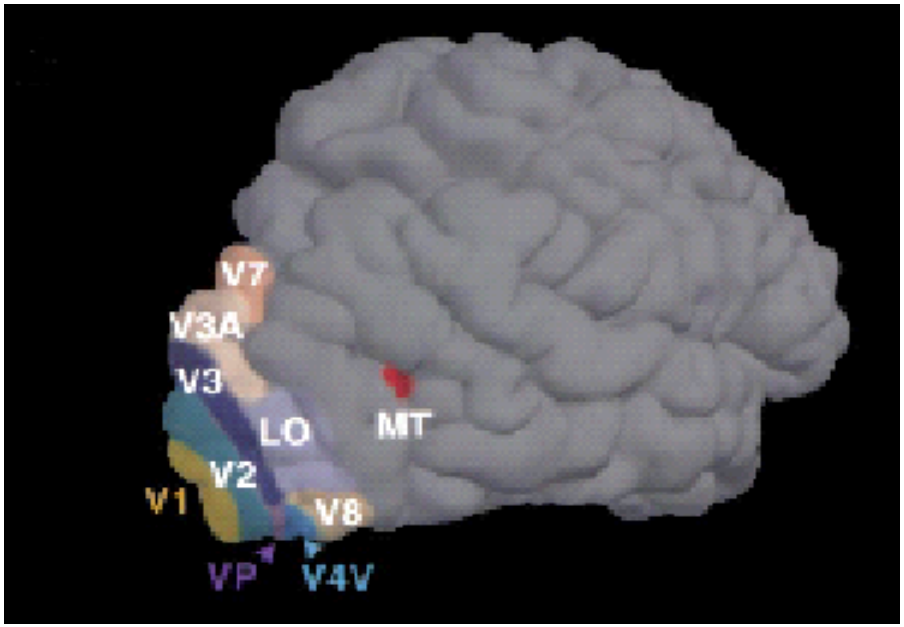
Homonymous hemianopia therapies

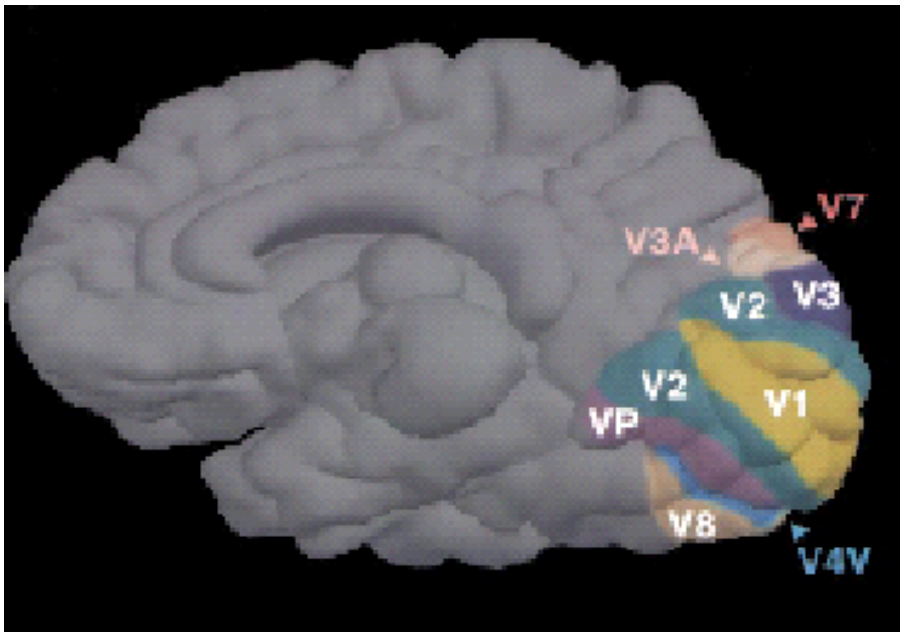
- optical devices
- compensatory oculomotor strategies
- visual restitution therapy

Visuo-spatial neglect

- mechanisms of visuo-spatial neglect
- treatment methodologies
- pharmacological interventions

The Visual Brain





Multiple areas in the visual brain which process object and spatial information

Homonymous Hemianopia (HH) - the scale of the problem

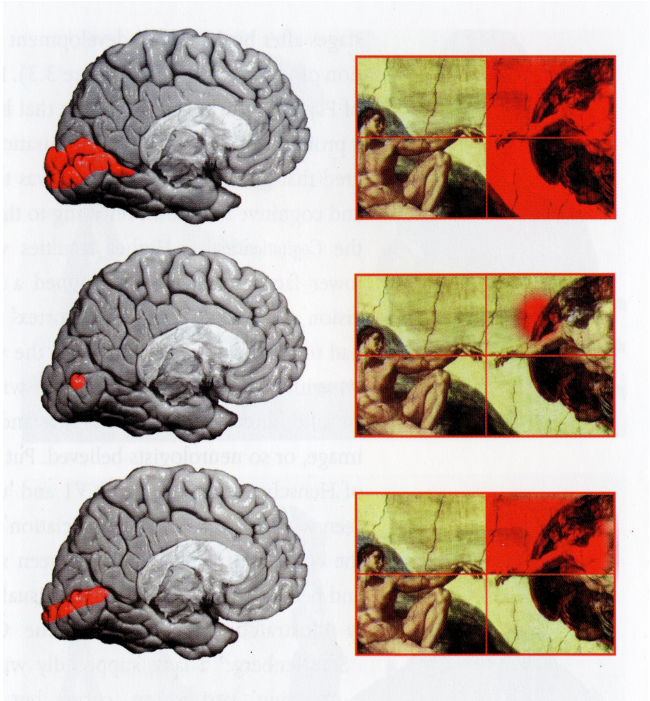
- 60% of patients with unilateral post-chiasmal brain damage have a HH field defect
- Commonest aetiologies are cerebral infarction, haemorrhage, closed head injury, tumour and hypoxia
- An HH leads to a poorer prognosis for successful rehabilitation from stroke

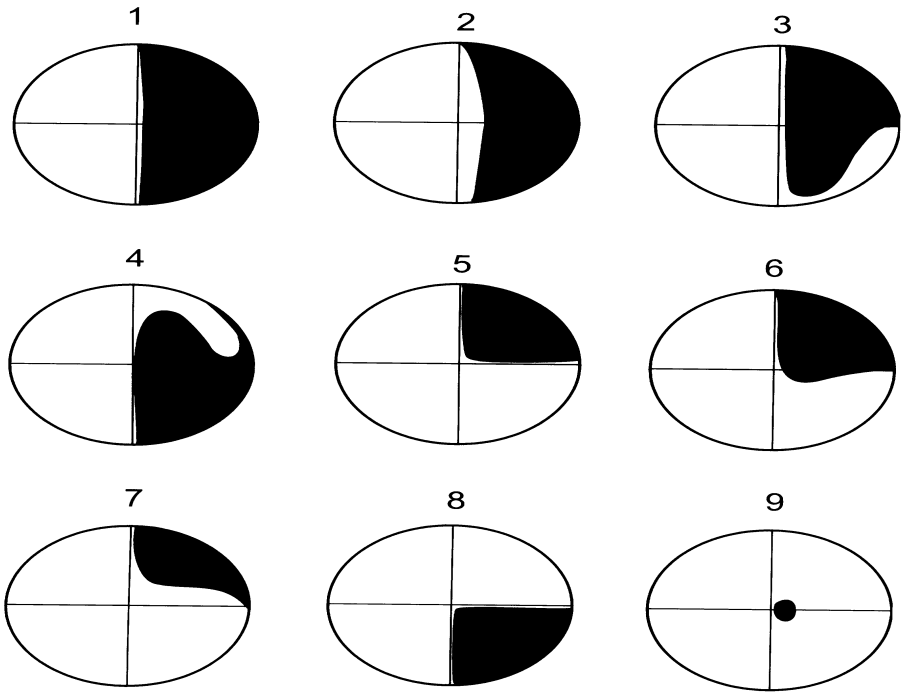
Typical difficulties of daily-life activity in patients with homonymous hemianopia

- Impaired visual exploration (incidence 60%) leading to difficulty in:
- Noticing persons or relevant objects
- Avoiding obstacles
- Driving
- Hemianopic reading deficits (incidence 80%) (as central 5 deg required)
  - RHH difficulty perceiving words and sentences due to loss of parafoveal perceptual window and abnormal saccades during reading
  - LHH difficulty returning to beginning of next line of text

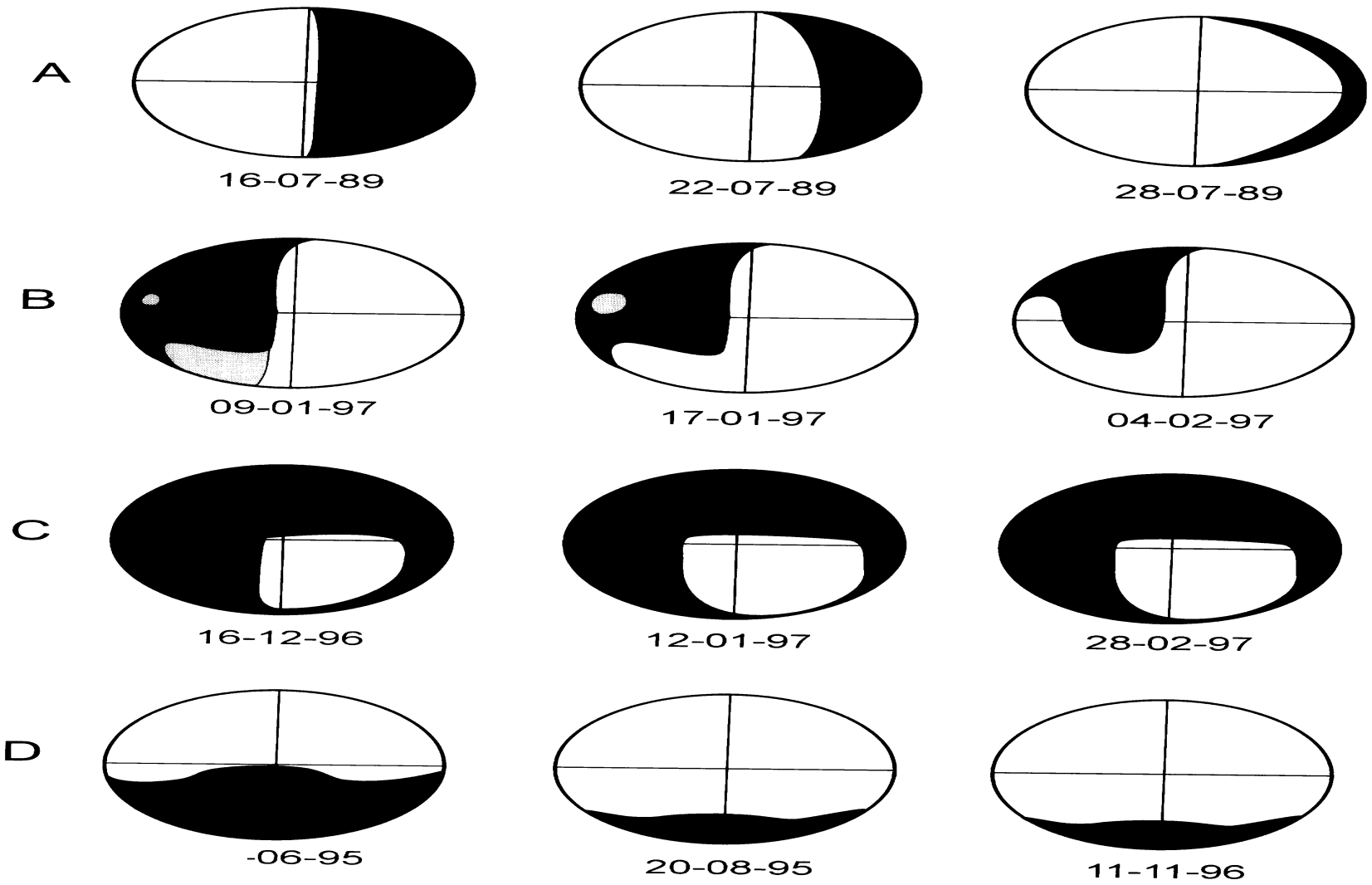
Generally accepted facts about HH

- Lesions of the geniculostriate pathway result in complete visual loss in the topographically-related area of the visual field





Recovery in the early stages does occur



Possible causes of recovery of vision following homonymous hemianopia

Approximately 40% of patients experience varying degrees of spontaneous recovery of their visual defect (Zhang et al 2006) – Why?

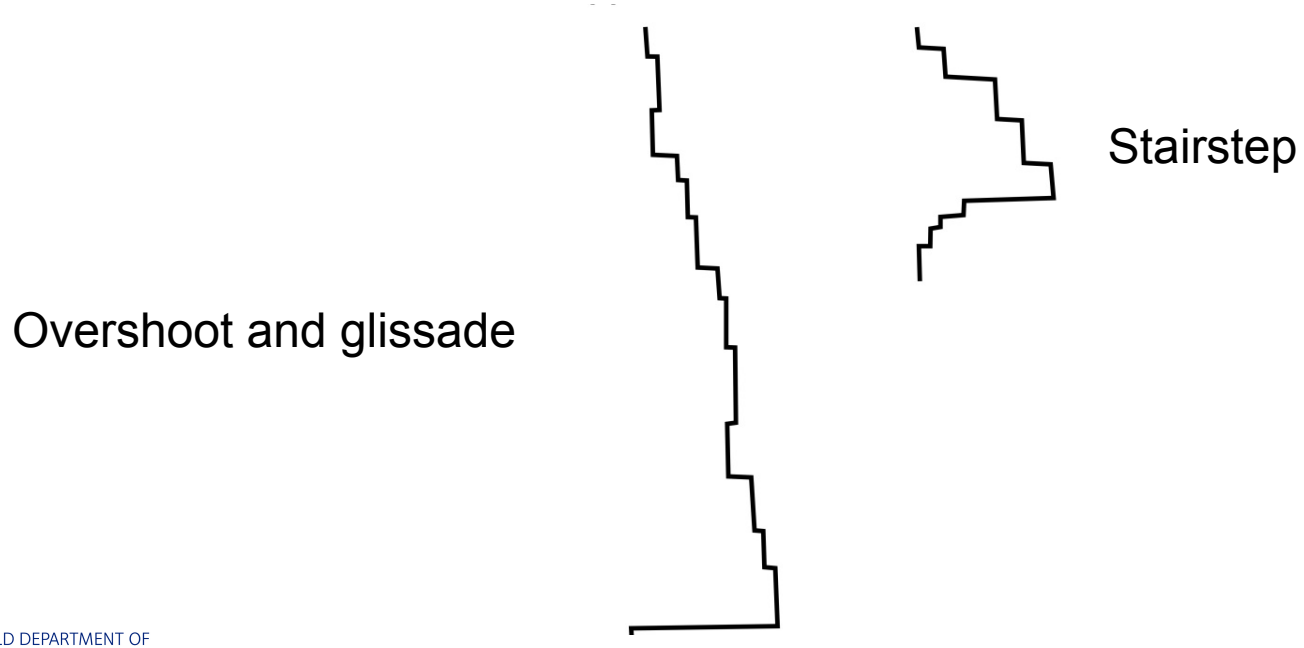
- spontaneous recovery
- active reorganisation of visual system - neuroplasticity
- development of extensive and rapid scanning eye movements into the blind field

<u>Factors predictive of visual field recovery</u>

- incomplete lesions
- shallow gradient between blind and seeing field
- residual metabolism in damaged area

Generally accepted facts about HH

- Patients with established field defects develop maneuvers designed to compensate for their visual loss



Treatment modalities for homonymous hemianopia

- Optical aids

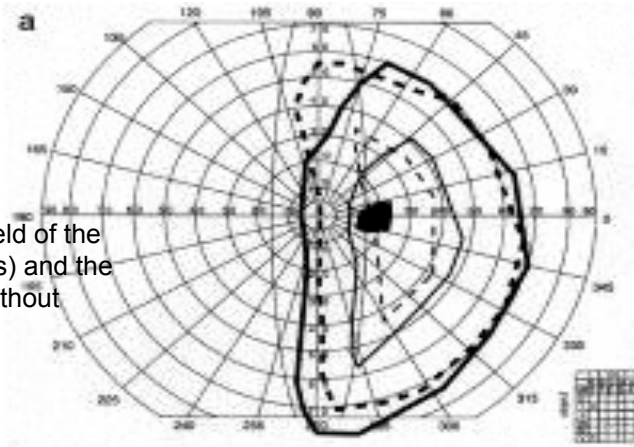
- Visual restorative training
  - visual field recovery - visual restitution therapy
  - saccadic compensatory therapy

OPTICAL THERAPY

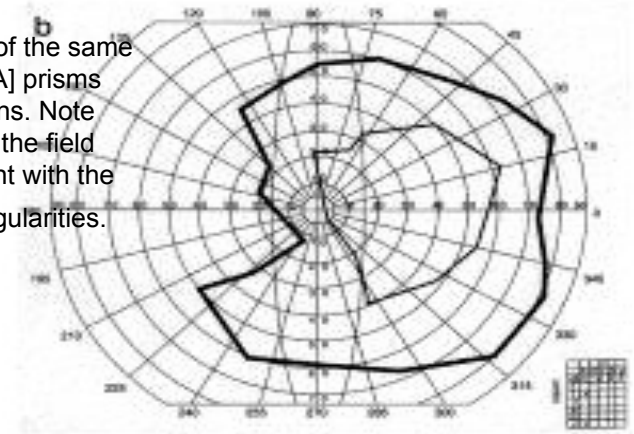
- Aims to improve vision by distorting or replacing part of the intact visual field with part of the damaged field
- Mirrors attached to spectacle frames, partially reflecting mirrors, dichroic mirrors, reversed telescopes, prisms, wide angle lenses and closed-circuit TV monitors
- Standard prisms
- Vision multiplexing
- Prism adaptation

MONOCULAR SECTORAL PRISMS RESTRICTED TO THE PERIPHERAL FIELDS

Fresnel prisms (40 [DELTA] base-out) are placed in the upper and lower peripheral segments across the whole lens. For a patient with right hemianopia, the prisms are placed on the right lens only. The effect of the prisms is to expand the field by about 20° in the lower and upper fields. The effect is maintained at all horizontal positions of gaze.



a: A left hemianopic field of the right eye (dashed lines) and the left eye (solid lines) without macular sparing.



b: The binocular field of the same patient with 40 [DELTA] prisms base-out on the left lens. Note that the asymmetry in the field expansion is consistent with the small pre-existing irregularities.

Peli E, 2002, Optom Vis Sci (79) 569-580

67% chose to continue to wear prism at end of 9 wk study (Giorgi et al 2009)

VISUAL TRAINING

- Visual field restorative techniques
- Compensatory oculomotor strategies for visual exploration

RESTORATIVE THERAPIES FOR HOMONYMOUS HEMIANOPIA

- Visual Field Restitution

  - visually stimulate partially defective areas, the transition zone between blind and normal visual field using computer-based programme (Sabel – NovaVision)

- Treatment for Hemianopic Alexia

- Saccadic Compensatory Therapy

  - saccadic and visual exploratory (visual search) training to shift attention and perform saccades into the blind hemifield thereby enlarging the field of gaze

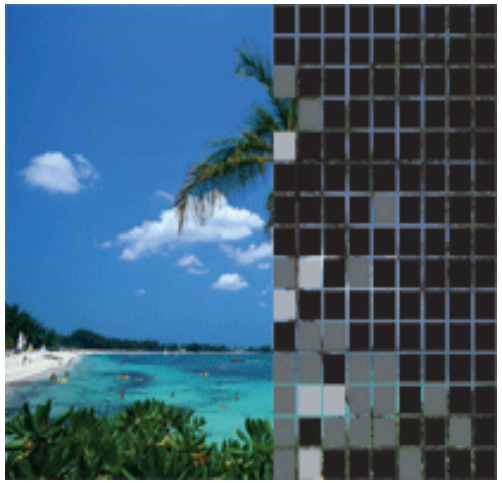
  - reading training

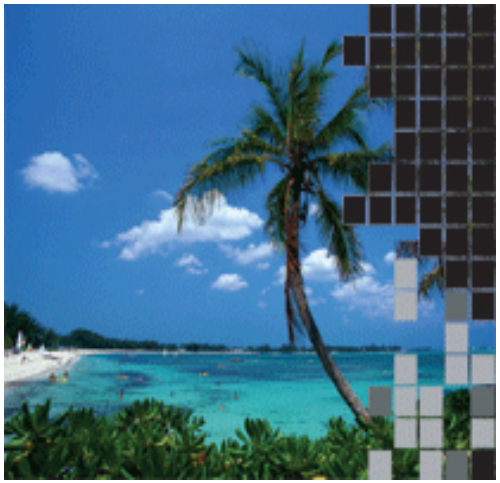
VISUAL FIELD RESTITUTION

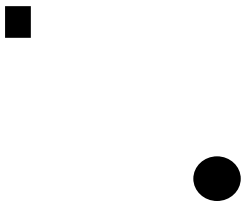
- Enormous controversy surrounds the question of whether any training techniques can significantly reverse visual field loss in hemianopes

- Technique involves repeatedly presenting visual targets at the transition zone between the intact and damaged visual field sector

NovaVision - Visual Restoration Therapy

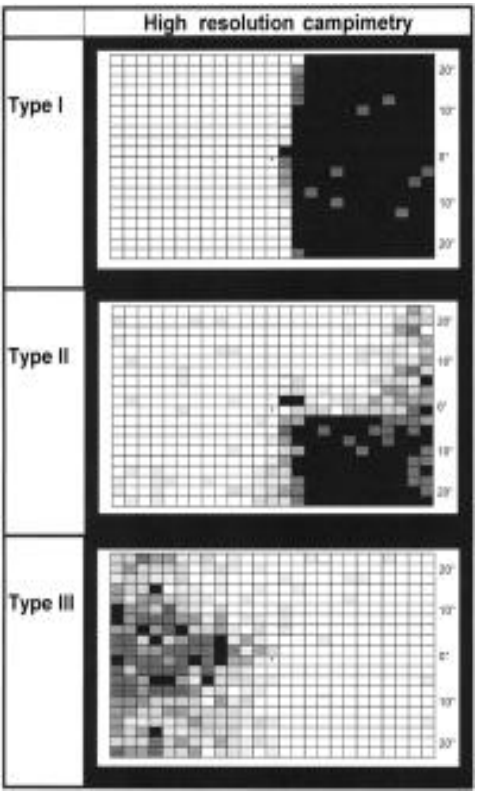




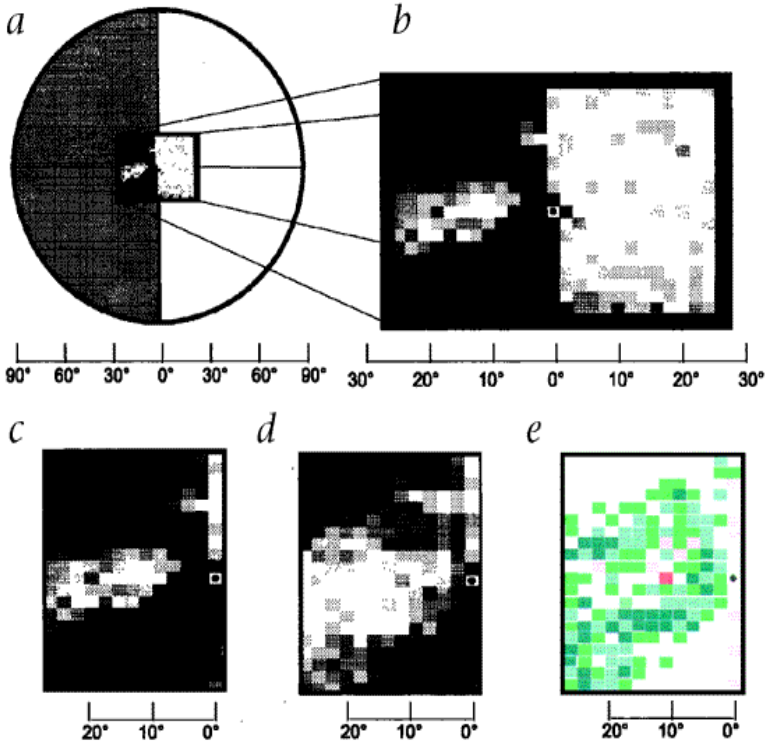


High resolution perimetry

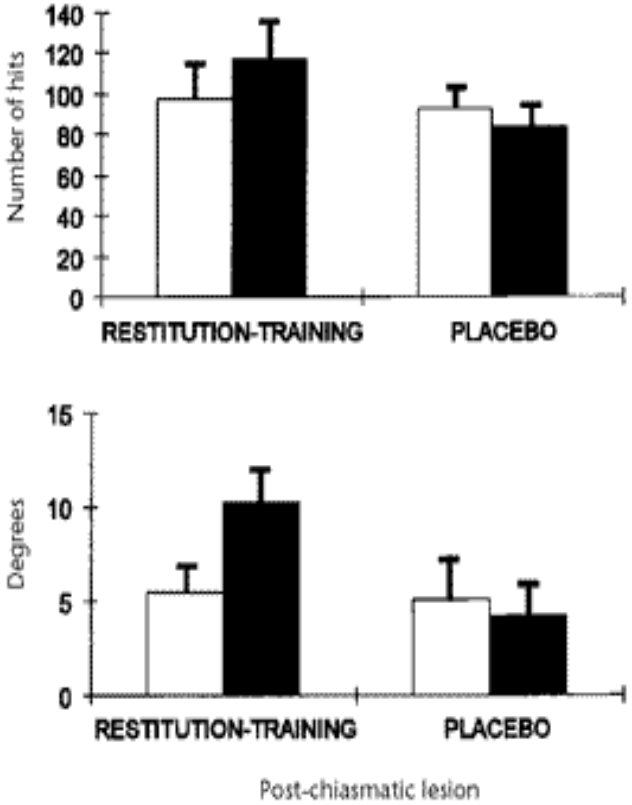
Diagnosis of residual vision using high resolution campimetry



Results of the training of a female patient after stroke due to occlusion of posterior cerebral artery



Effects of VRT in a group of patients with optic nerve or post-chiasmic injury



Bernhard Sabel
Kasten et al Nature Med 1998

Controlled perimetry suggests no improvement of visual field

EXTENDED REPORT

Does visual restitution training change absolute homonymous visual field defects? A fundus controlled study

J Reinhard, A Schreiber, U Schiefer, E Kasten, B A Sabel, S Kenkel, R Vonthein, S Trauzettel-Klosinski

Br J Ophthalmol 2005;**89**:30–35. doi: 10.1136/bjo.2003.040543

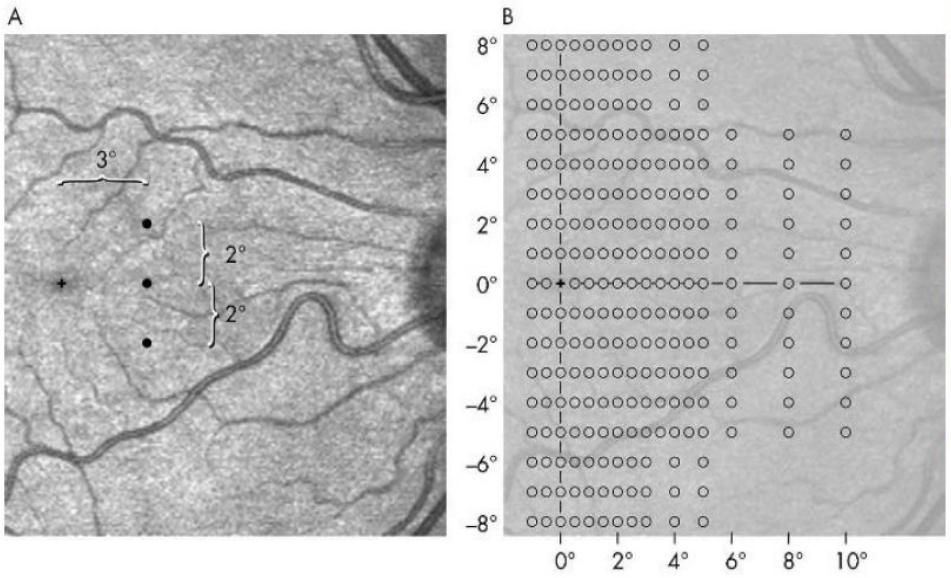


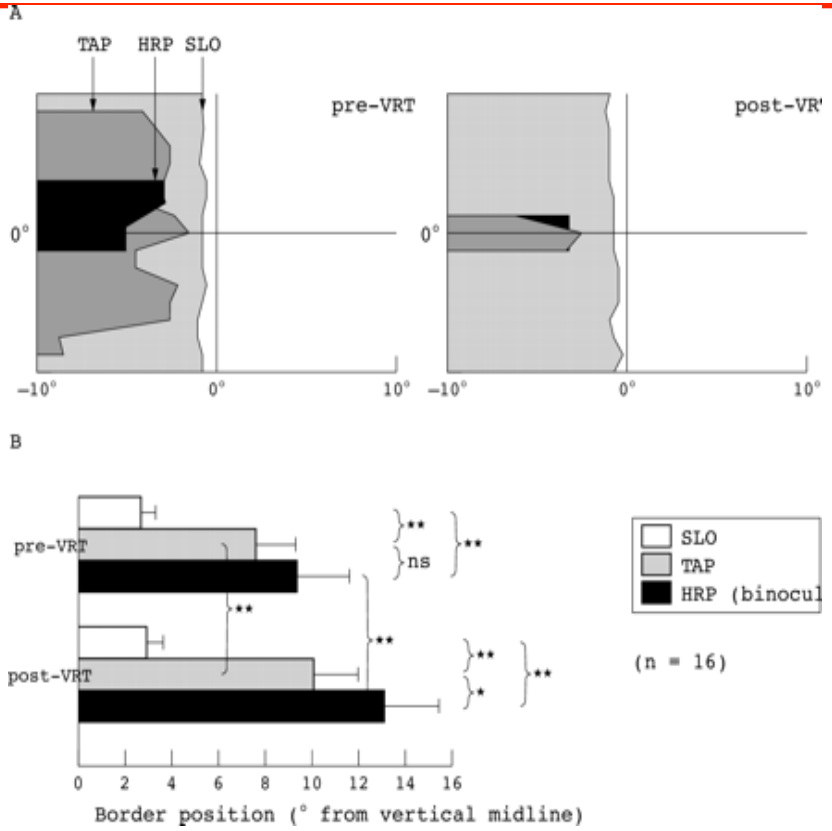
Figure 1 Stimulus presentation in the SLO. The investigator sees stimuli and retina simultaneously. When fixation is central—that is, the foveola was located on the fixation cross, he presented a test triplet (120 ms presentation time). In (A) a triplet with 3° eccentricity and 2° inter-dot distance is shown. The patient's task was to say how many and which of the dots he could see (for example, the upper, the lower, and/or the middle). Eccentricity and inter-dot distance were varied in random order; altogether a grid of 241 locations in central visual field was tested (B). The grid covered an area ranging 1° towards the healthy field and 10° in the blind field, vertically plus or minus 8°.

N = 17

Scanning laser ophthalmoscope

Are the differing results due to the perimetric techniques?

- SLO - scanning laser ophthalmoscopy
- TAP - Tubingen automated perimetry
- HRP - high resolution perimetry



Sabel et al BJO 2005

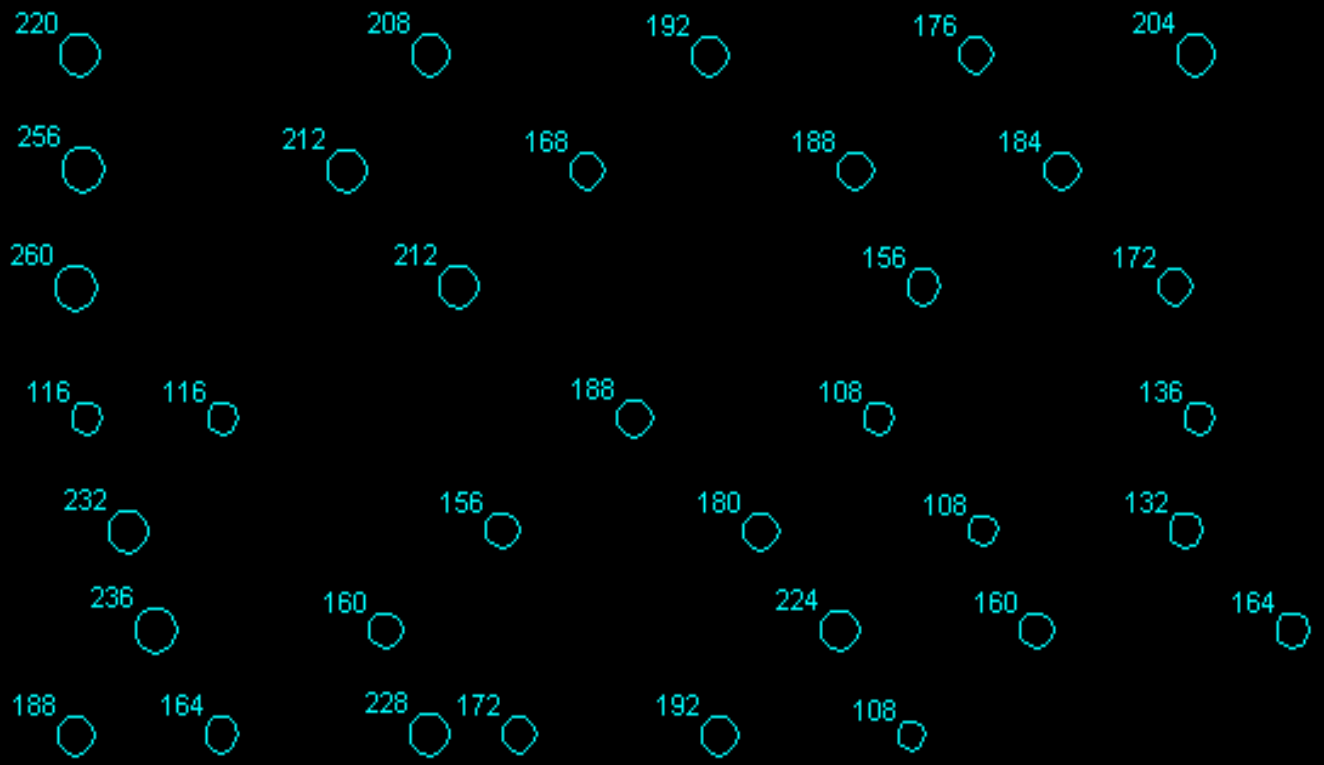
OR: due to poor fixation

A treatment for hemianopic alexia?

Patients with R-sided HH show slow left to right reading – using induced small field OKN can this be improved?

Passenger Paul Lynch stunned airport security staff when he proved his identity by showing them the cover of a Guinness Book of Records. Paul did not have any photo ID with him when he checked in at Stansted for a no-frills GO flight to Edinburgh.

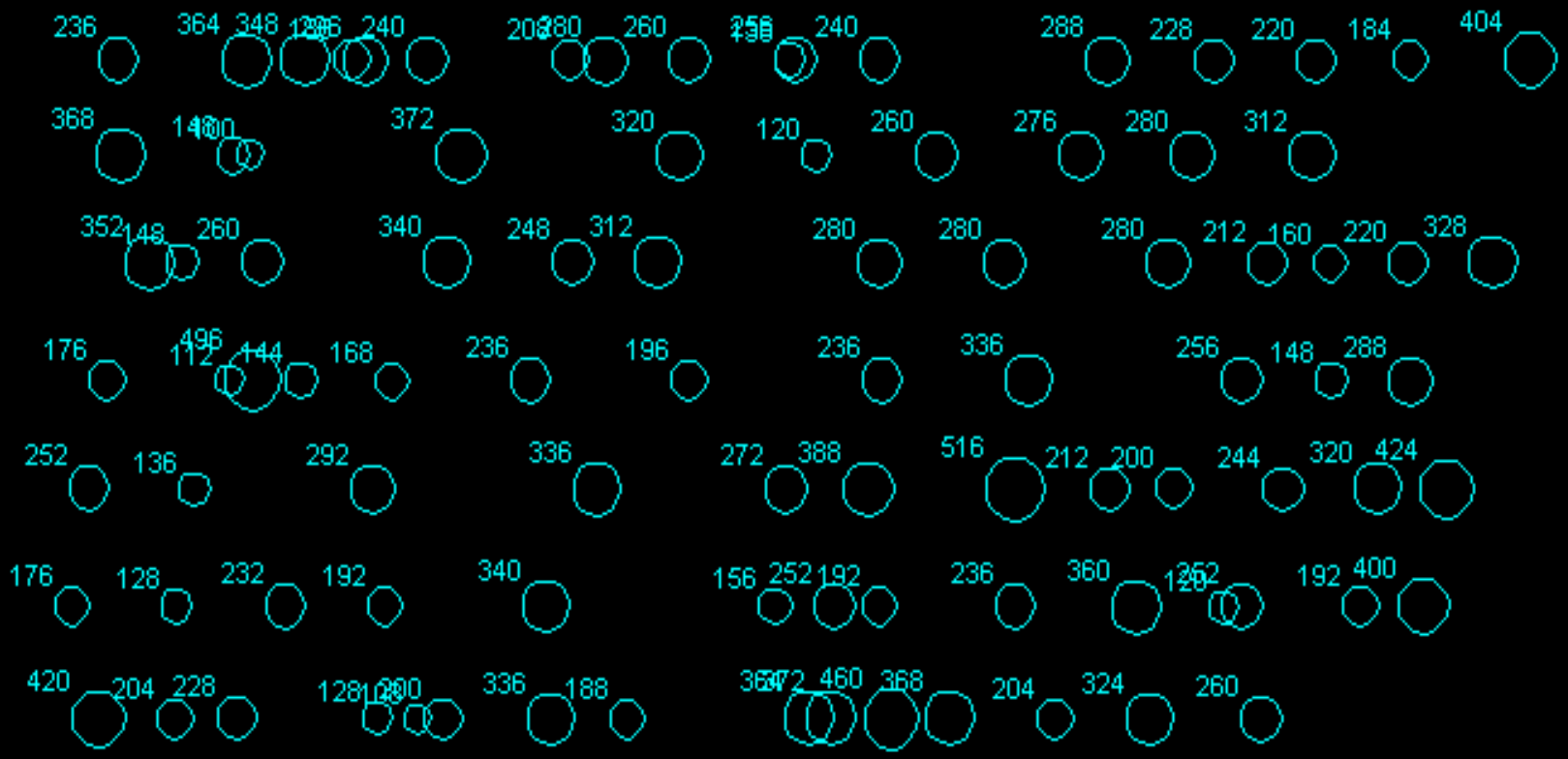
Courtesy of Dr Alex Leff



text reading fixations – normal subject

36 fixations 45 words: ratio = 0.8

Courtesy of Dr Alex Leff



text reading fixations – hemianopic alexia

93 fixations 45 words: ratio = 2.1

Optokinetic therapy improves text reading in patients with hemianopic alexia

A controlled trial

G.A. Spitzyna, MSc
R.J.S. Wise, FRCP
S.A. McDonald, PhD
G.T. Plant, FRCP
D. Kidd, FRCP
H. Crewes, BA
A.P. Leff, PhD

Address correspondence and reprint requests to Dr. Alexander Leff, Wellcome Department of Imaging Neuroscience, 12 Queen Square, London, WC1N 3BG, UK
a.leff@fil.ion.ucl.ac.uk

ABSTRACT Objective: An acquired right-sided homonymous hemianopia can result in slowed left-to-right text reading, called hemianopic alexia (HA). Patients with HA lack essential visual information to help guide ensuing reading fixations. We tested two hypotheses: first, that practice with a visual rehabilitation method that induced small-field optokinetic nystagmus (OKN) would improve reading speeds in patients with HA when compared to a sham visual rehabilitation therapy; second, that this therapy would preferentially affect reading saccades into the blind field. **Methods:** Nineteen patients with HA were entered into a two-armed study with two therapy blocks in each arm: one group practiced reading moving text (MT) that scrolled from right to left daily for two 4-week blocks (Group1), while the other had sham therapy (spot the difference) for the first block and then crossed over to MT for the second. **Results:** Group 1 showed significant improvements in static text reading speed over both therapy blocks (18% improvement), while Group 2 did not significantly improve over the first block (5% improvement) but did when they crossed over to the MT block (23% improvement). MT therapy was associated with a direction-specific effect on saccadic amplitude for rightward but not leftward reading saccades. **Conclusion:** Optokinetic nystagmus inducing therapy preferentially affects reading saccades in the direction of the induced (involuntary) saccadic component. This is the first study to demonstrate the effectiveness of a specific eye movement based therapy in patients with hemianopic alexia (HA) in the context of a therapy-controlled trial. A free Web-based version of the therapy used in this study is available online to suitable patients with HA. NEUROLOGY 2007;68:1922-1930

Spitzyna….Leff, Neurology (2007)

Rehabilitation site http://www.readright.ucl.ac.uk/

Read-Right Hemianopic Alexia Rehabilitation
UCL Institute of Neurology

UCL

Home | Patient | Clinical Staff | Help

Welcome, a.leff@fil.ion.ucl.ac.uk | Sign out

Welcome to Read-Right

Read-Right is a research application developed to aid the rehabilitation of acquired alexia sufferers (patients who have problems with reading after having had a stroke or head injury).

This research project was instigated by Dr Alex Leff a Consultant Neurologist at The Wellcome Trust Centre for Neuroimaging at UCL.

This website contains rehabilitation materials (moving text) that have been shown to improve text reading speeds in patients with Hemianopic Alexia (HA) in three published studies.

The therapy consists of reading moving text. Improvements usually occur after 7-14 hours of therapy.

The average effect of therapy is to improve reading speeds by 20%, but not everyone with HA will benefit.

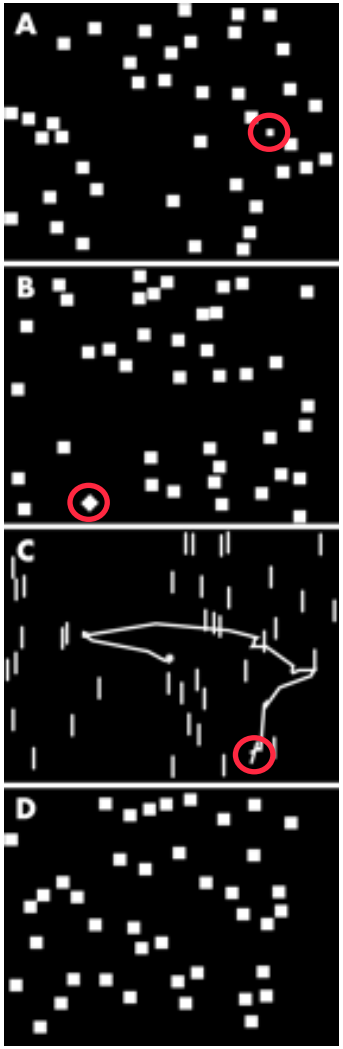
The rehabilitation materials should only be used by patients with Hemianopic Alexia. There is no evidence that they will improve the reading speeds of people with developmental dyslexia - often referred to as 'dyslexia', or people with generalized language problems following brain injury ('aphasia').

Access to the moving text and self-test materials is free of charge.

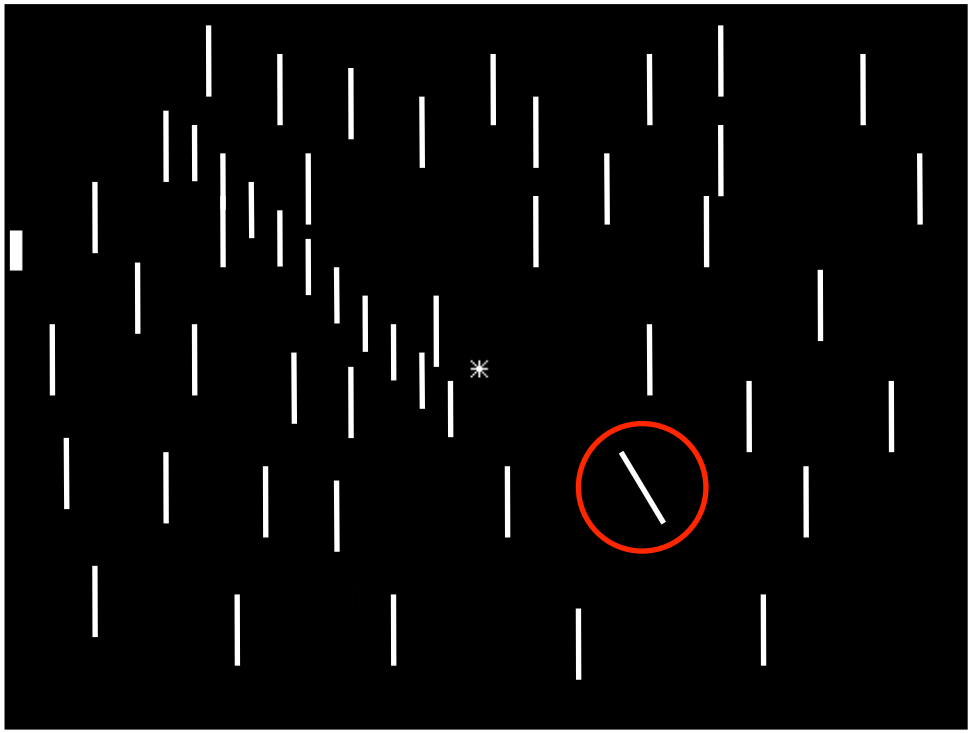
COMPENSATORY OCULOMOTOR STRATEGIES FOR VISUAL EXPLORATION

- Steps in training programs
  - Practicing large saccades into the blind hemifield (inappropriately small saccades)
  - Practicing visual search on projected slides (improve spatial organization of eye movements)
  - applying both techniques to real life scenarios

- Parameters used to judge the success of these techniques:
  - Improvements in response time and error rates
  - Enlargements in visual field and visual search field
  - Objective improvements in ADL
  - Subjective improvements-questionnaires



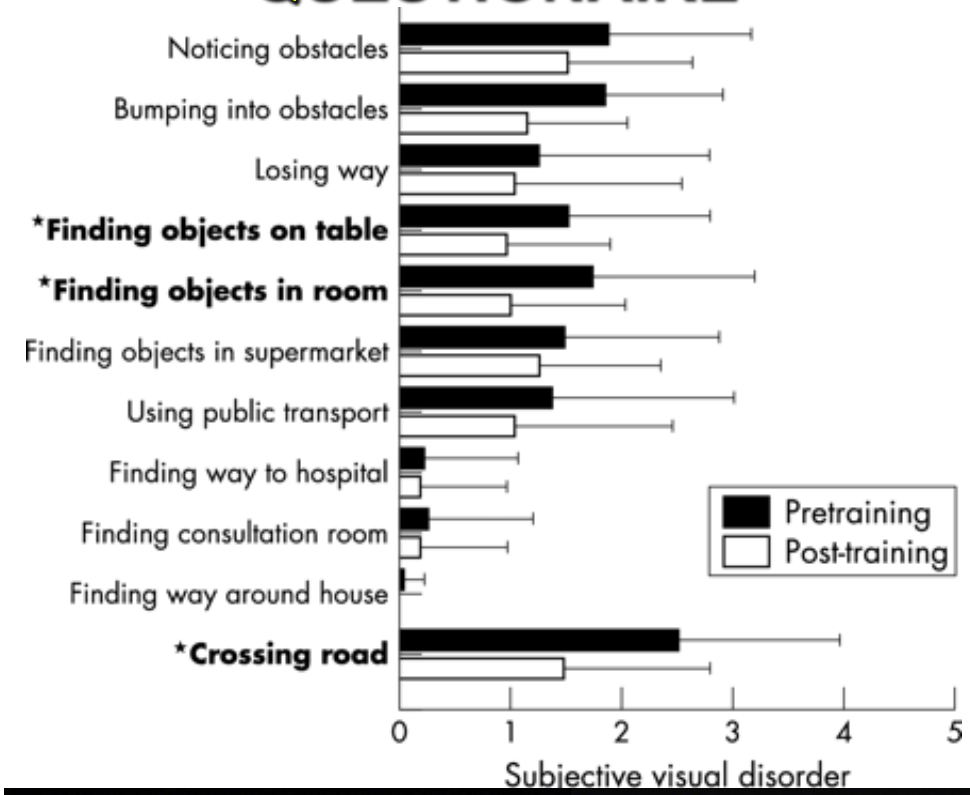
Visual search training technique

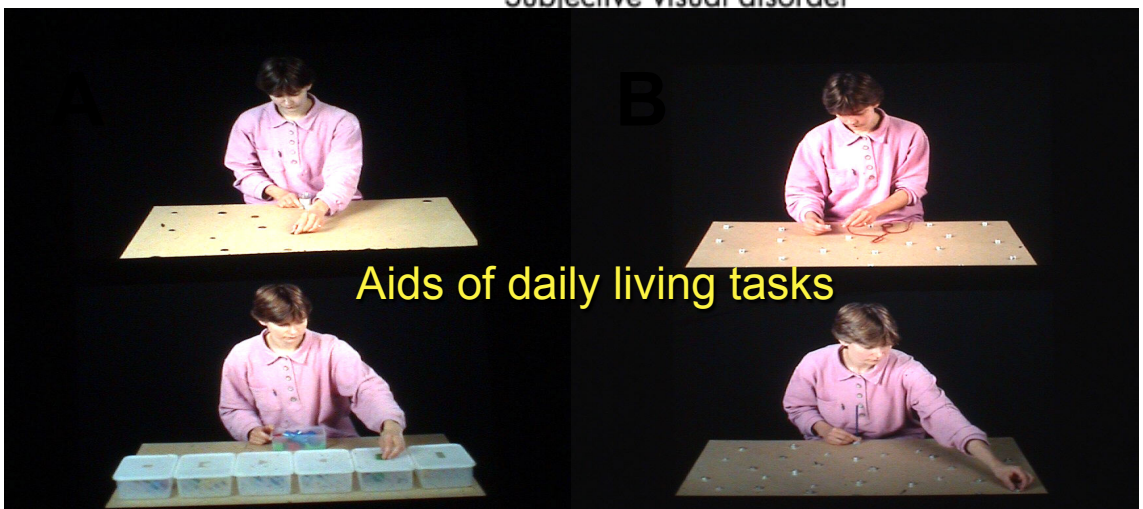


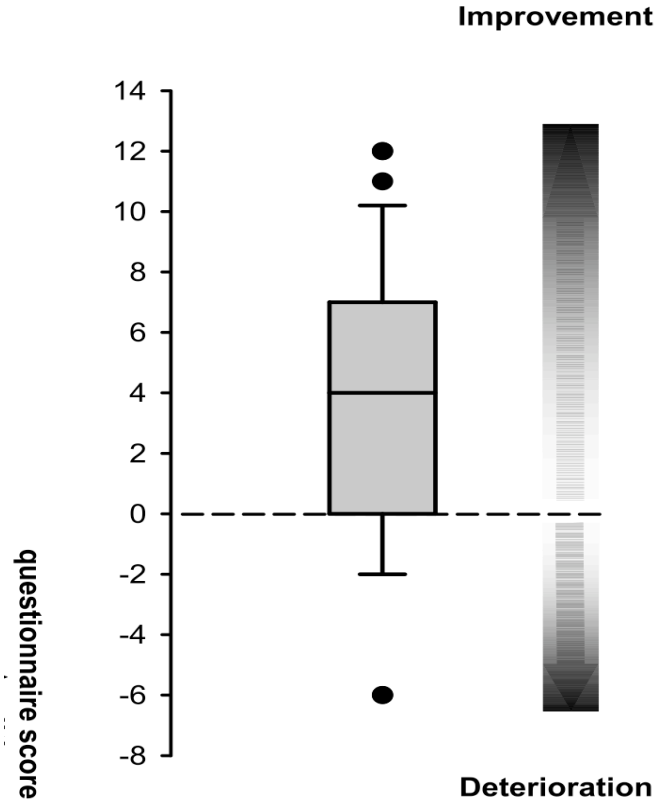
20 x 40 minute sessions over one month; 600 trials/session

n = 29

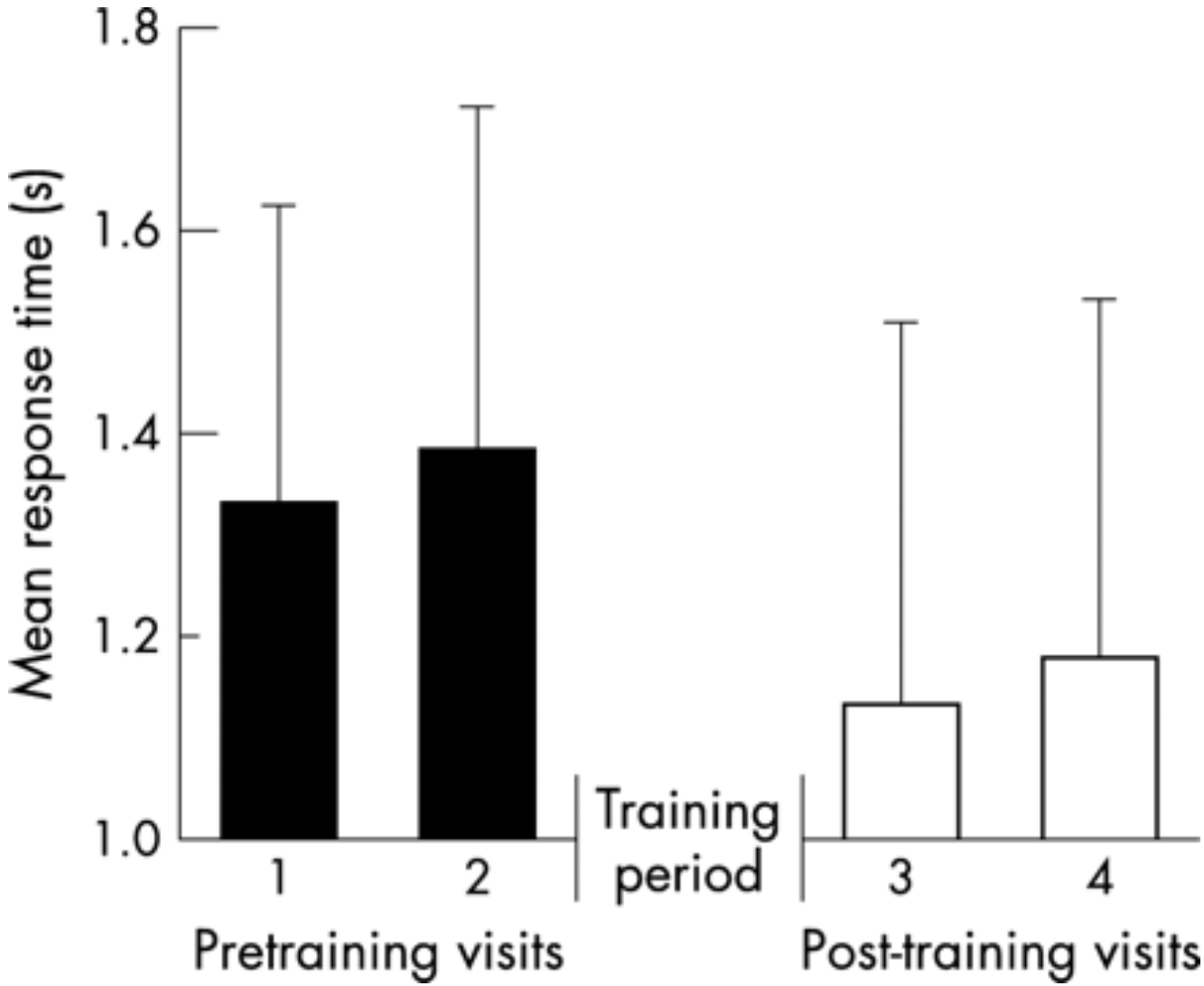
VISUAL DISORDER QUESTIONAIRE



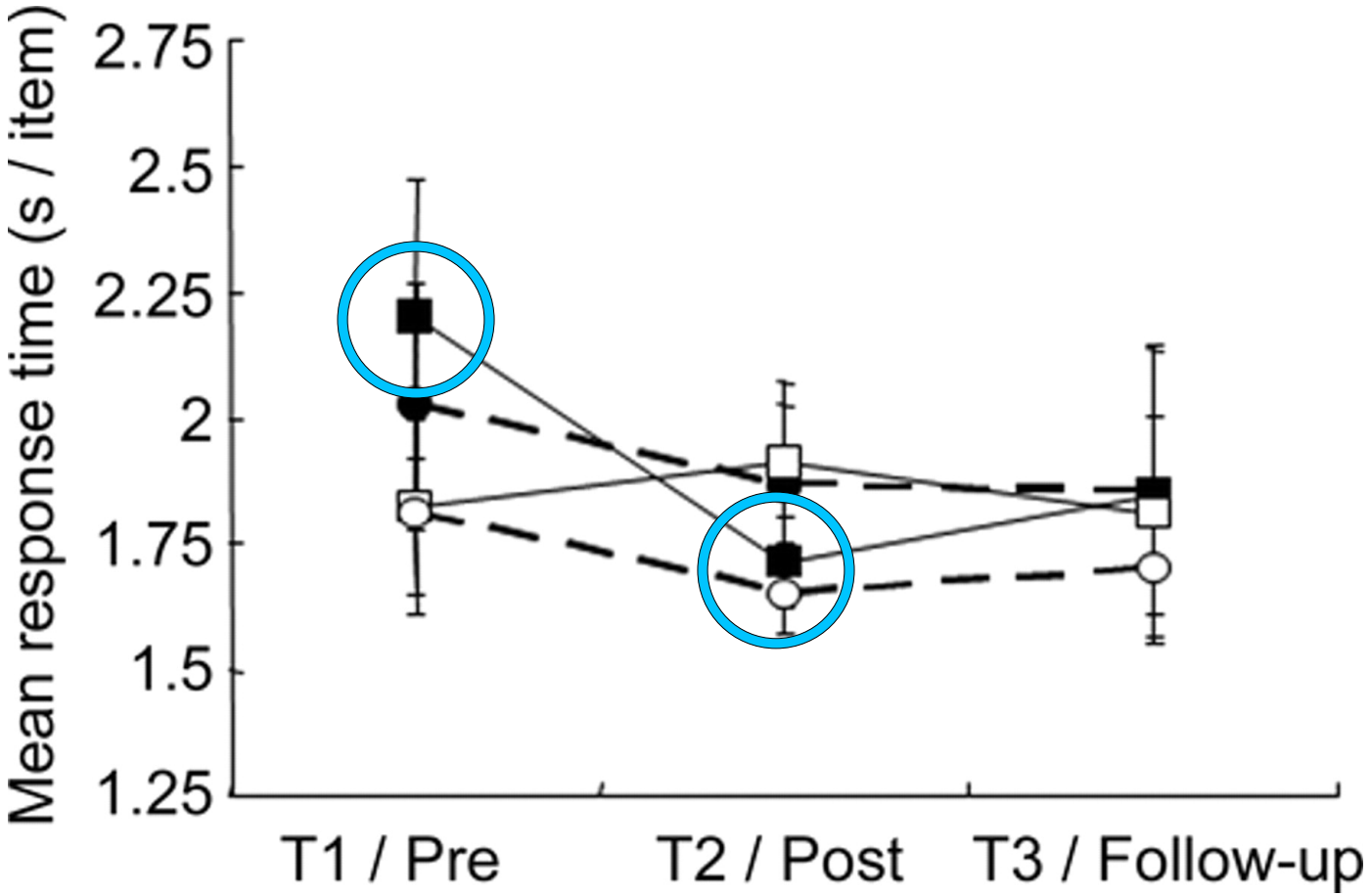




Pambakian et al, JNNP, 2005


Mean response time (s)
1.8
1.6
1.4
1.2
1.0
1
2
Training period
3
4
Pretraining visits
Post-training visits

Tubingen cross-over study



Roth, T. et al. Neurology 2009;72:324-331

doi:10.1093/brain/awr356 Brain 2012: 135; 912–921 | 912

BRAIN
A JOURNAL OF NEUROLOGY

Rehabilitation of reading and visual exploration in visual field disorders: transfer or specificity?

Susanne Schuett,[1,2] Charles A. Heywood,[2] Robert W. Kentridge,[2] Ruth Dauner[3] and Josef Zihl[3,4]

Conclusions:

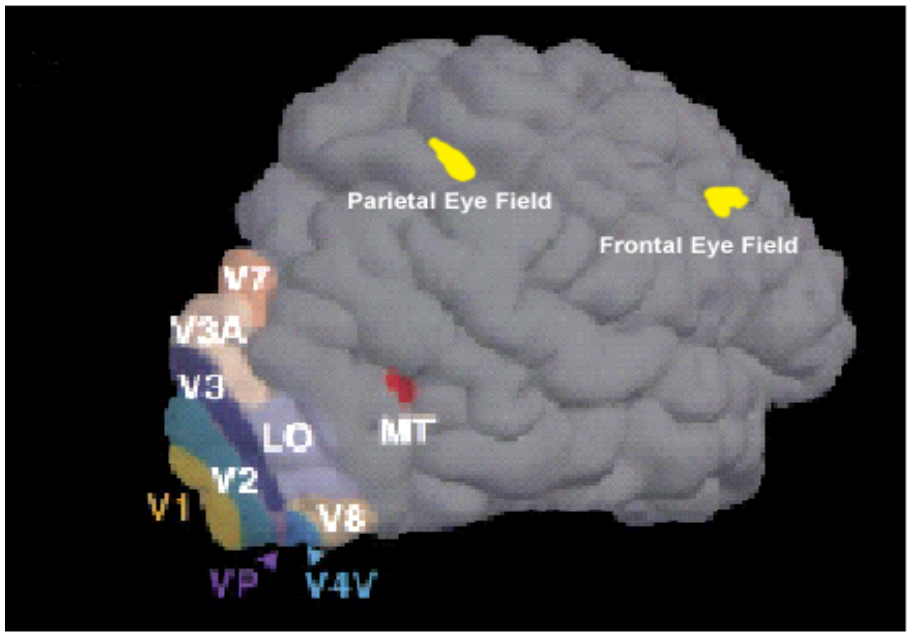
Both VET and RT significantly reduce the reading and visual exploration impairments

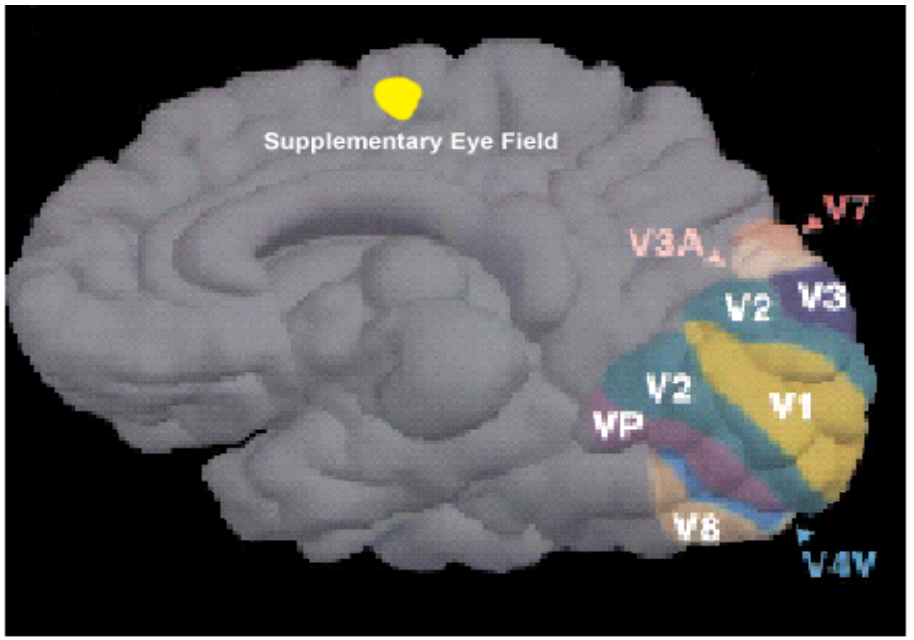
Training related improvements in reading and visual exploration are specific and task dependent

CONCLUSIONS

- Patients can improve their performance in visual search with specific practice by adopting one of a variety of compensatory eye movement strategies.
- This is usually reflected by shorter RT.
- These changes translate to improved overall function assessed both objectively with tasks representing ADL, and subjectively using a visual disorder questionnaire, substantiating the view that they represent a robust training effect that is non-modality specific, due to post lesional plasticity .
- There was no concomitant enlargement of the visual field.

The Attentive Brain & Eye Fields





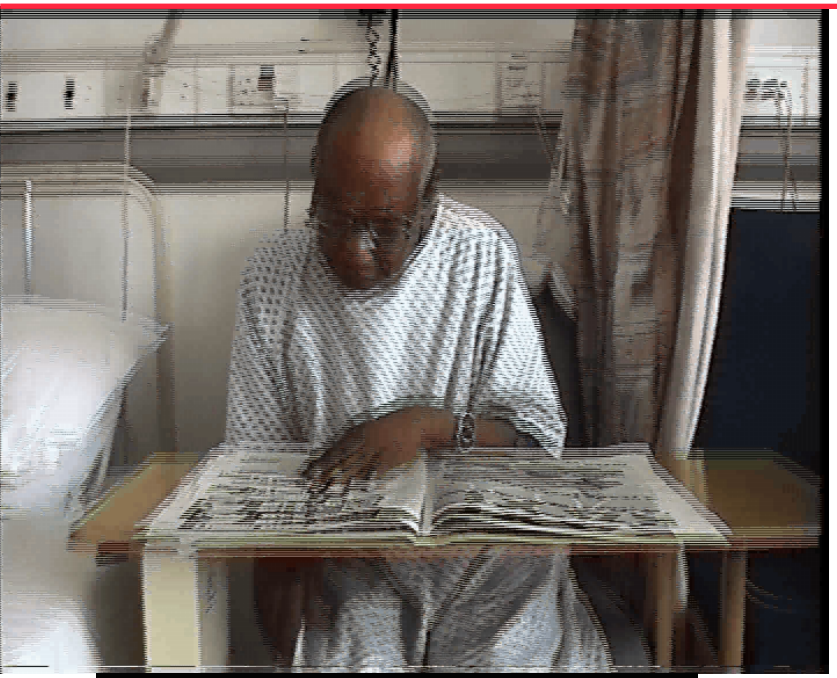
How the brain selects information and guides the eyes


S

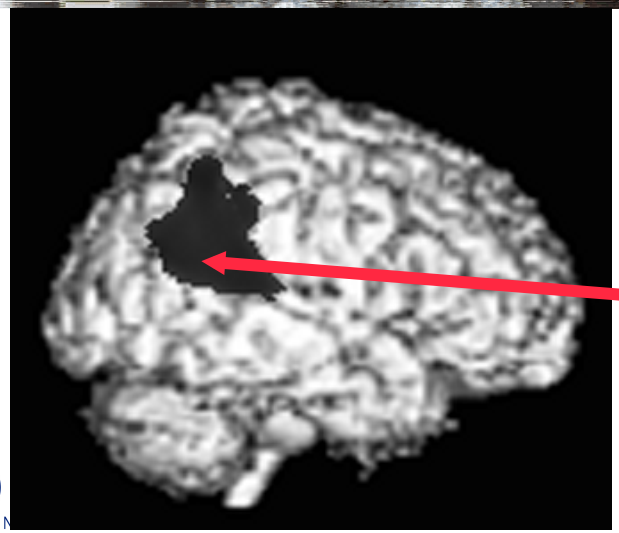
Attentional blindness
The brain has a limited attentional capacity

Simmons DJ, Chabris CF (1999) Perception 28:1059-1074

UNILATERAL HEMI-NEGLECT



Unilateral neglect or inattention is an impairment in the ability to orient toward, perceive or act on stimuli from one side, despite preserved primary motor sensory functions



Right inferior parietal lobe

Space exploration in neglect reveals leftward deficit

Tracking eye movements of neglect patients as they view natural scenes

Hemianopia vs visuo-spatial neglect

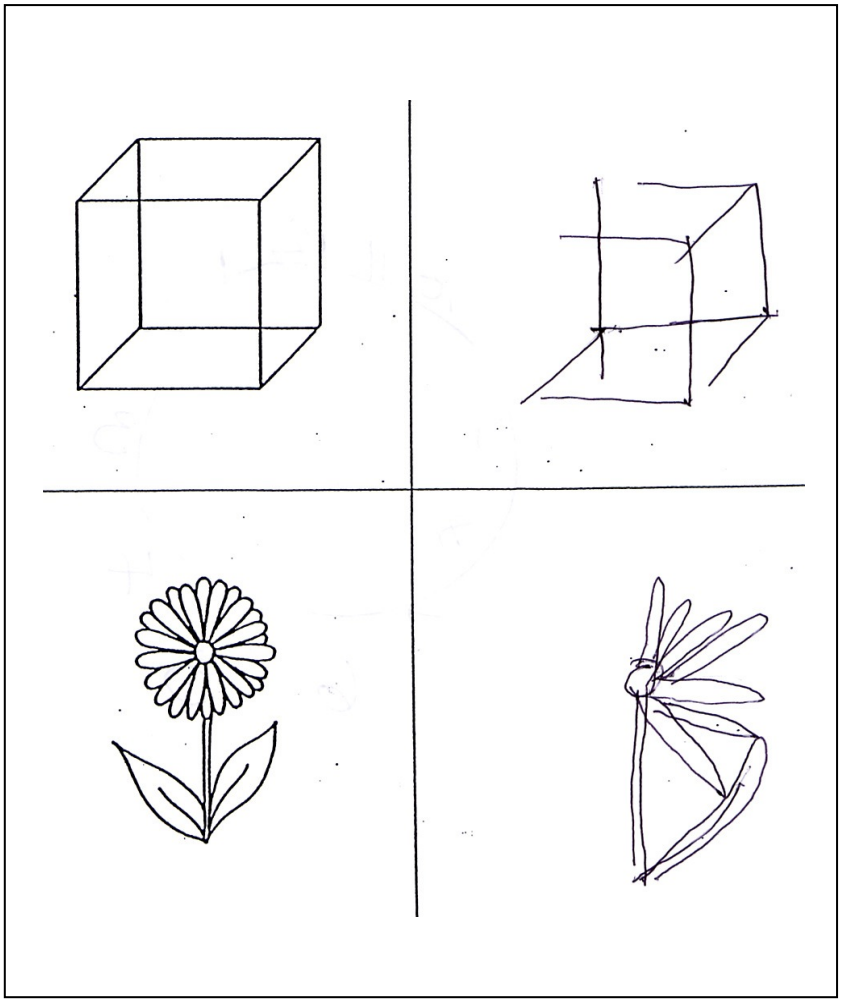
B

C

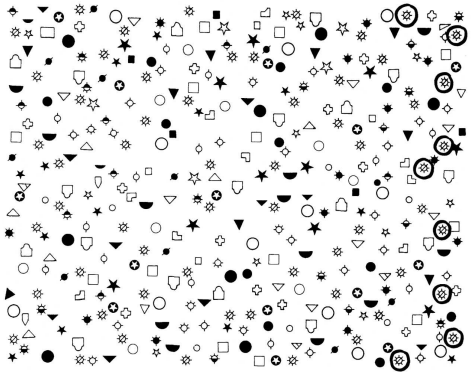
NEGLECT AFTER STROKE

- Is common and long-lasting after right hemisphere stroke
- Up to 70% rt hem patients may show some signs acutely
- Many patients (approx. 2/3) recover
- Poor prognosis for independent function in those who don't
- No established treatments
- Therefore a need to understand underlying mechanisms
- Most investigators have focused on spatial deficits, consistent with classical views of anatomy of the syndrome

Copying or painting tasks may reveal leftward neglect



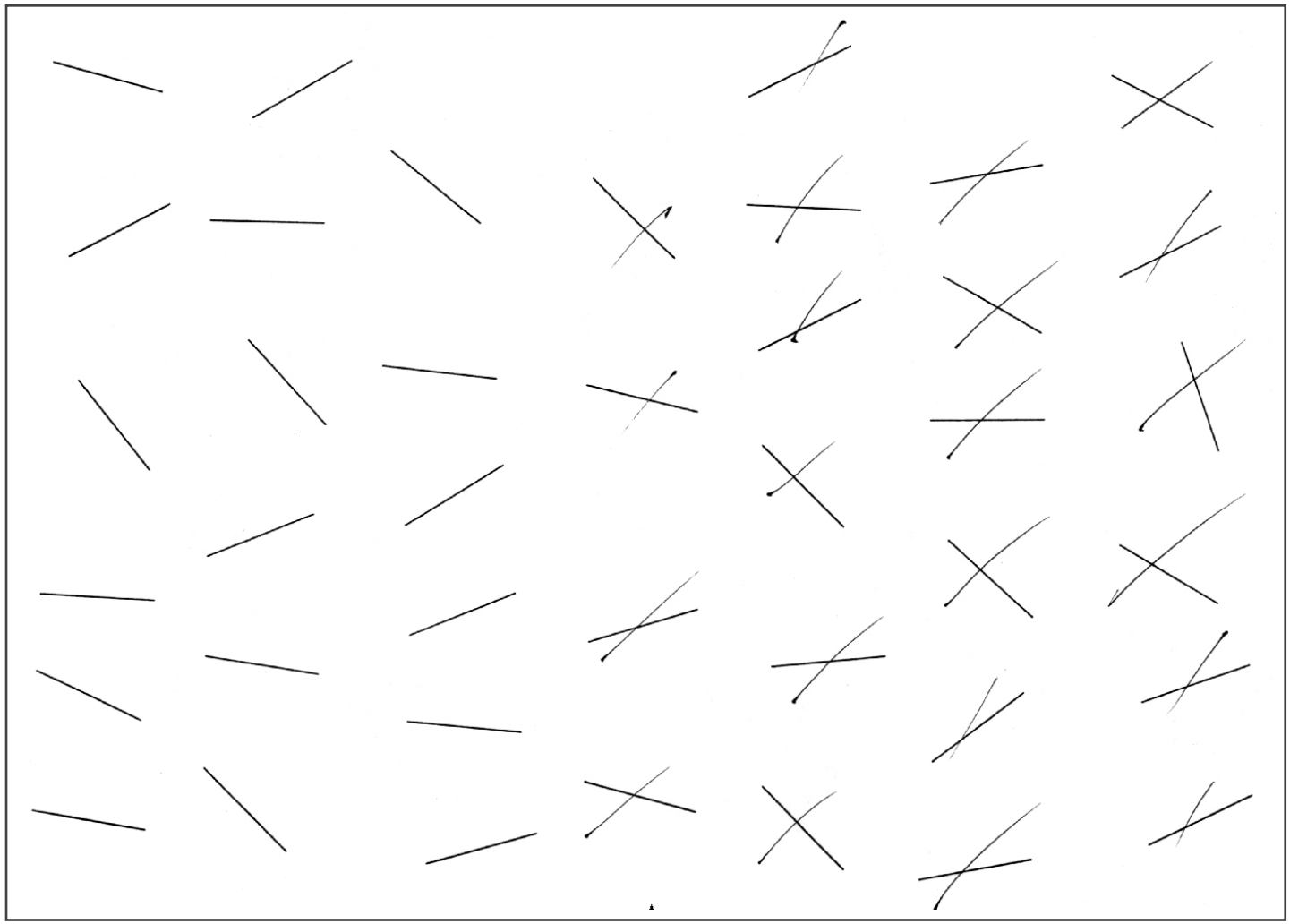
DEFICITS IN REPRESENTING LEFT SPACE CAN'T EXPLAIN SEVERAL ASPECTS OF NEGLECT



1 The severity of neglect is modulated by the clutter in the visual scene.

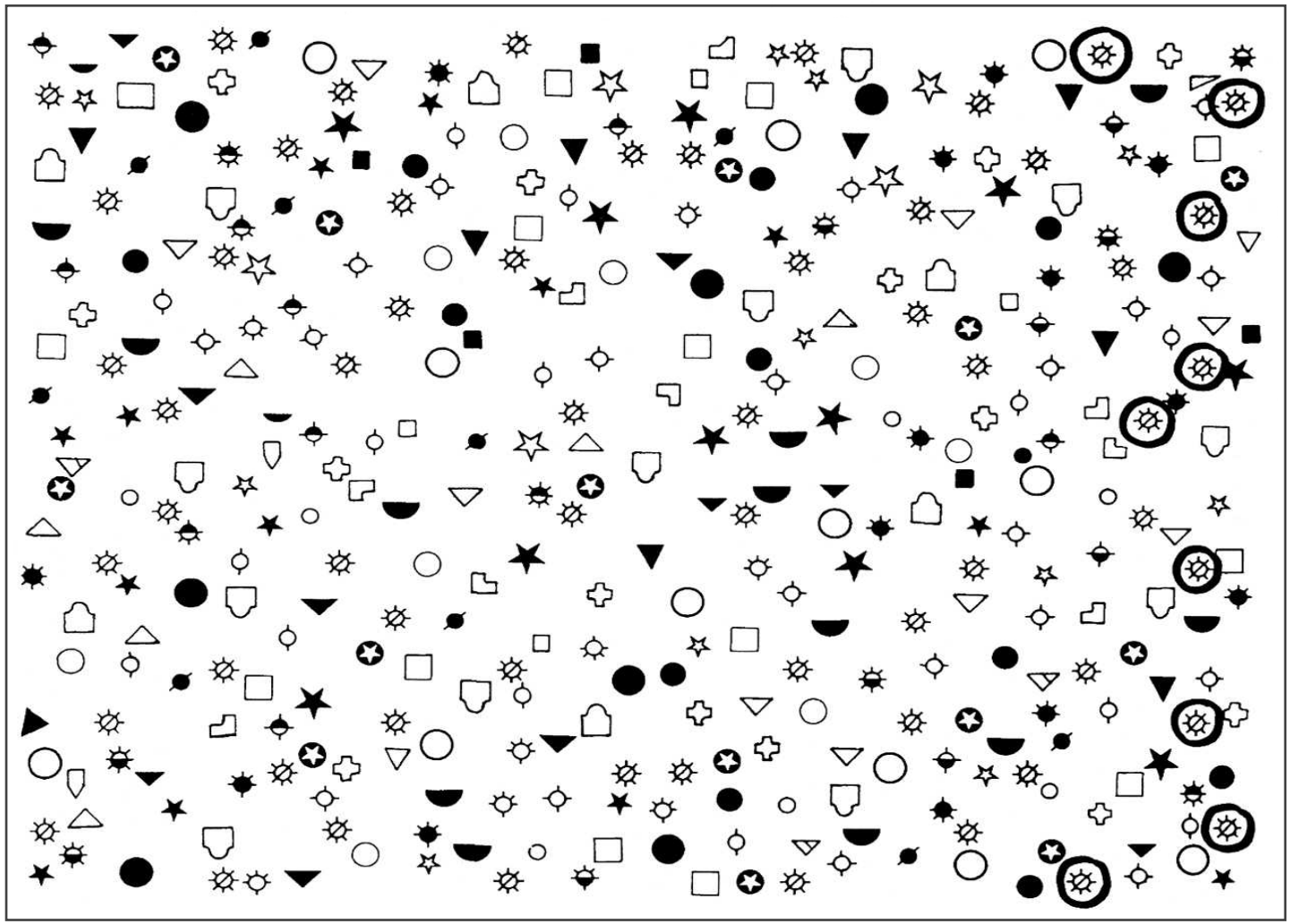
Cancellation task

reveals neglect of half sheet



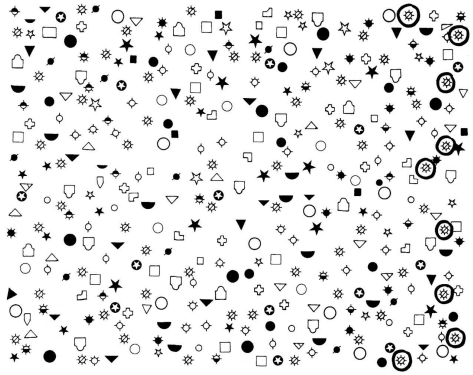
Same patient on same day

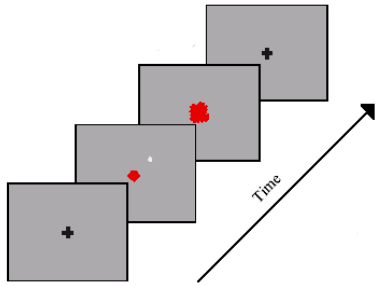
Neglect modulated by competing stimuli (distractors)



Hemianopia vs visuo-spatial neglect

DEFICITS IN REPRESENTING LEFT SPACE CAN'T EXPLAIN SEVERAL ASPECTS OF NEGLECT





1 The severity of neglect is modulated by the clutter in the visual scene.

2 Patients with right parietal lesions also have impaired detection on their supposedly good *right side*.

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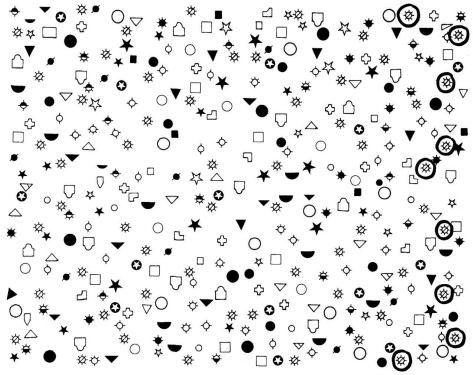
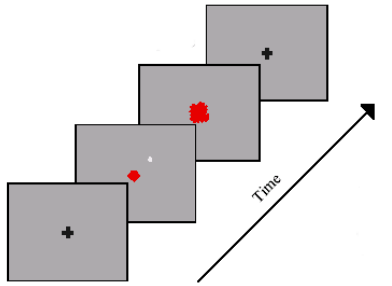
DEFICITS IN REPRESENTING LEFT SPACE CAN'T EXPLAIN SEVERAL ASPECTS OF NEGLECT





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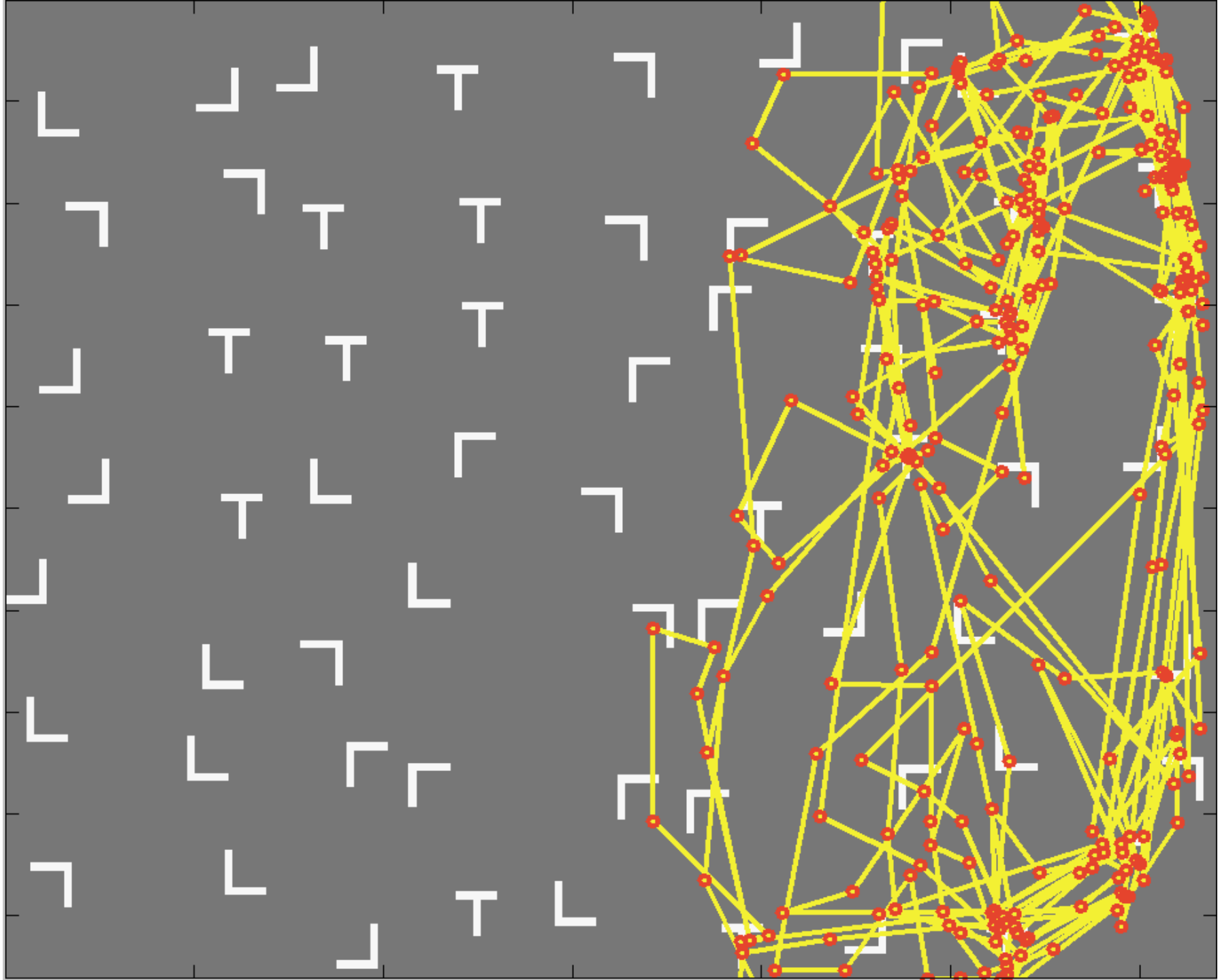


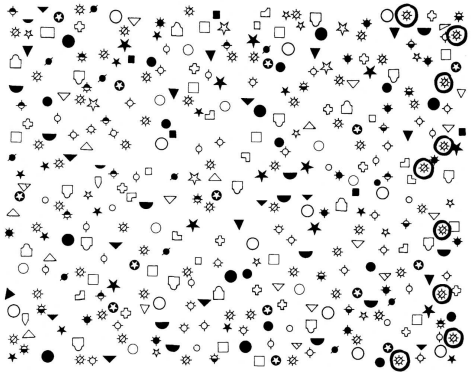
DEFICITS IN REPRESENTING LEFT SPACE CAN'T EXPLAIN SEVERAL ASPECTS OF NEGLECT

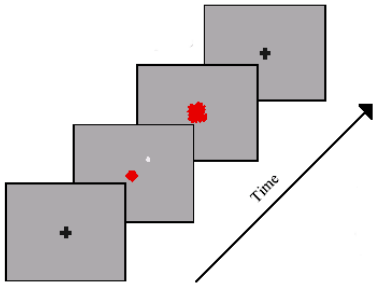
1. The severity of neglect is modulated by the clutter in the visual scene.

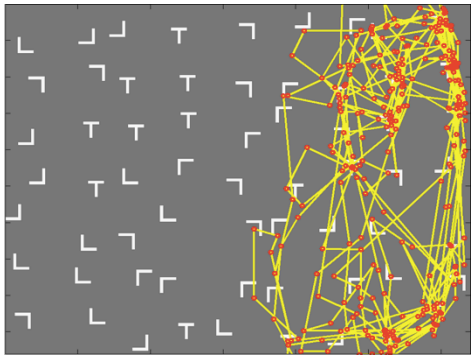
2. Patients with right parietal lesions also have impaired detection on their supposedly good right side.

3. Many neglect patients revisit locations *on the right*, failing to keep track of where they have looked before.

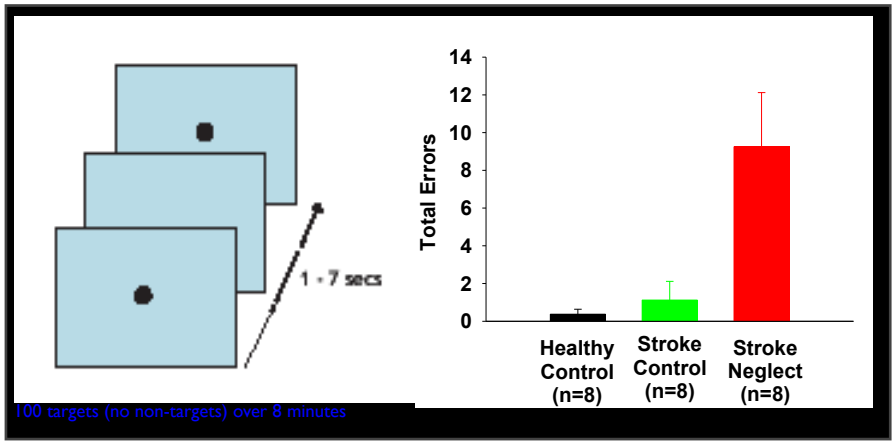
4. Neglect patients show deficits on non-spatial tasks



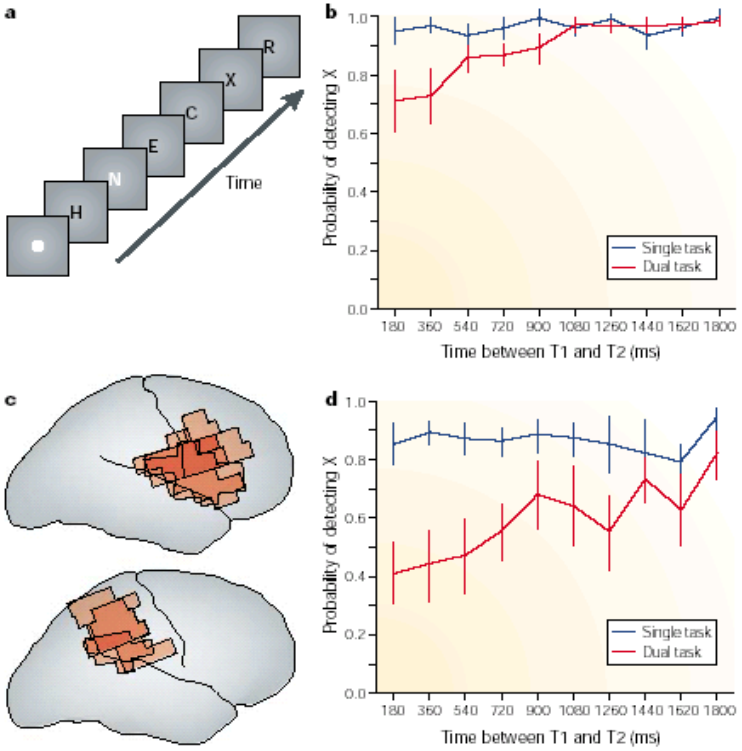




Non-spatial sustained attention and selective attention are also impaired in patients with spatial neglect



Impaired vigilance for central visual stimuli



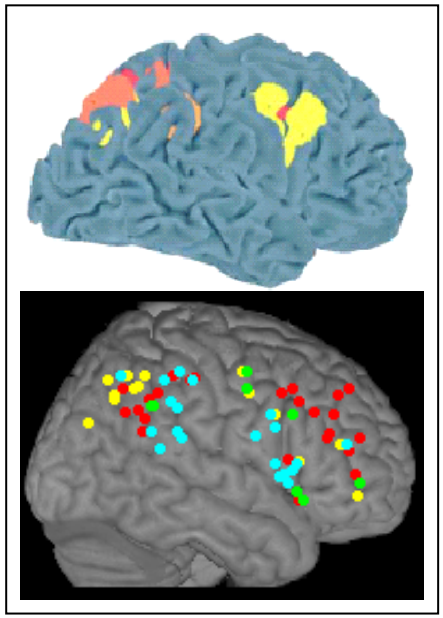
Abnormal 'attentional blink' indicative of reduced visual processing capacity

...otra, Coulthard et al *(2009))*

Husain *et al* (1997) *Nature*

Parietal cortex has both spatial and non-spatial functions

Visuo-spatial neglect is not a unified entity. It is a syndrome with different neglect patients have different combinations of cognitive/ behavioural deficits



Spatial deficits

- shifts of covert attention
- representations of space
- motor / pre-motor shifts
- spatial working memory

Non-spatial deficits

- sustained attention
- salience detection
- attentional capacity

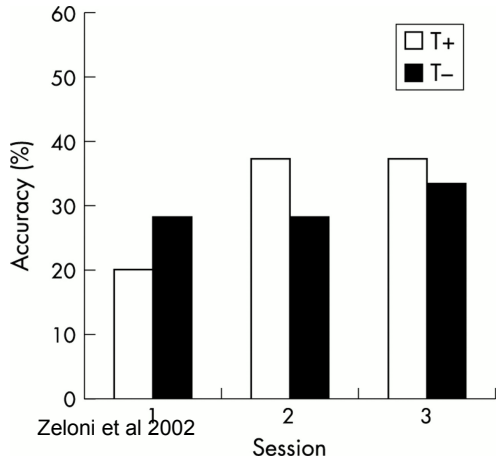
Non-spatial mechanisms may interact with spatial ones to define the severity and extent of neglect.

Treatment and rehabilitation of hemispatial neglect

- Scanning therapy and hemianopic patching
- Inducing shifts in spatial representations
- Prism adaptation
- Treating non-spatially lateralised deficits
- transcranial Direct Current Stimulation (tDCS)
- Galvanic stimulation
- Targeted pharmacological interventions

Scanning therapy and hemianopic patching

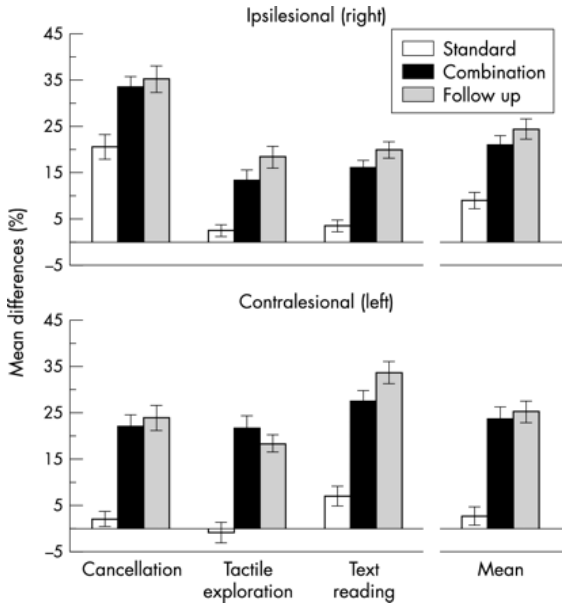
- Scanning therapy - encourage patients to direct gaze toward contralesional space eg red line on left margin for reading
- Failed to generalise to tasks outside of training environment; requires patients to be aware of deficit and deliberately modifying their behaviour (top-down)
- Hemianopic patching - goggles with occlusion of right good (ipsilesional) side of vision in each eye ie forcing patients to direct gaze to their contralesional side (Zeloni et al 2002)
- Modest effects - not well tolerated



Zeloni et al 2002

Inducing shifts in spatial representation

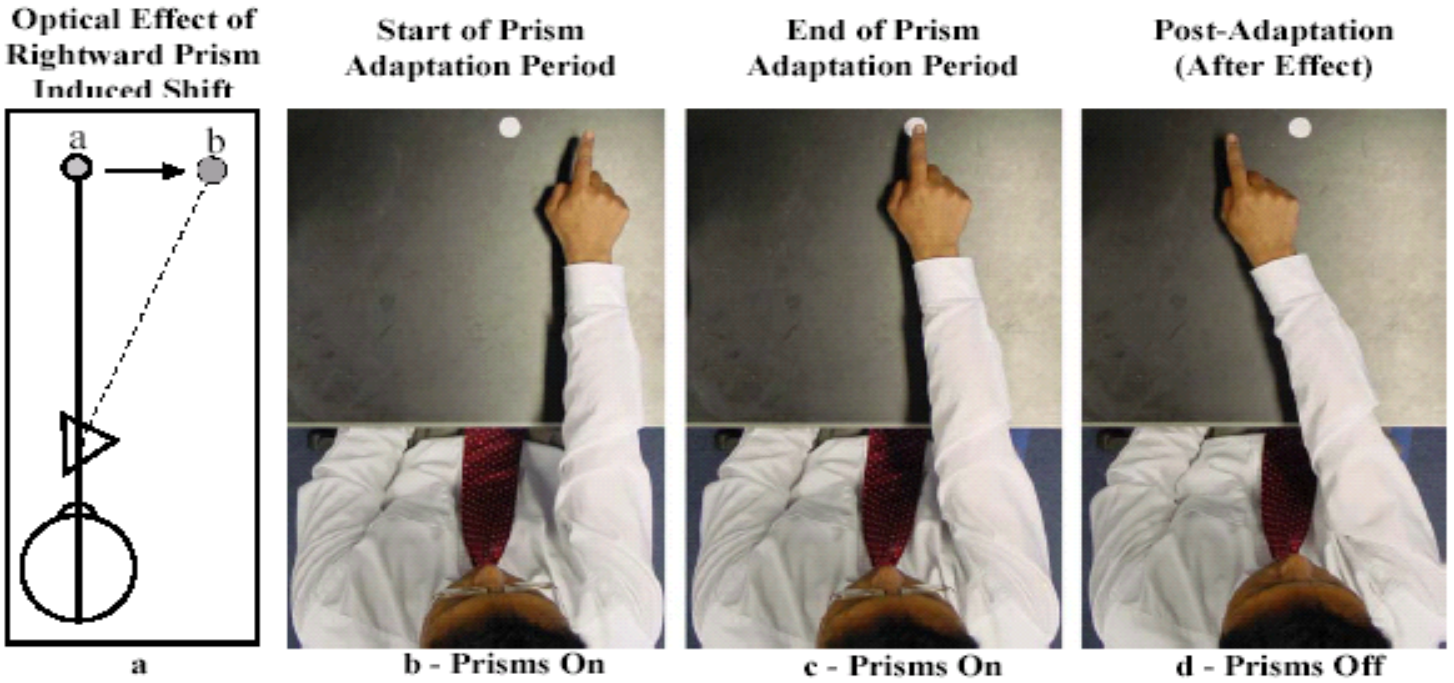
- Techniques to alter the impaired representation of space in neglect include: caloric or vestibular stimulation, contralesional limb activation, trunk rotation, neck muscle vibration, electrical stimulation of the neck
- Produce an automatic ("bottom-up") change in behaviour or recalibration of the sensorimotor mechanisms recruited
- All produce some improvement in neglect - some of which generalises



Exploration training +/- Neck vibration Schindler et al 2002

Prism adaptation

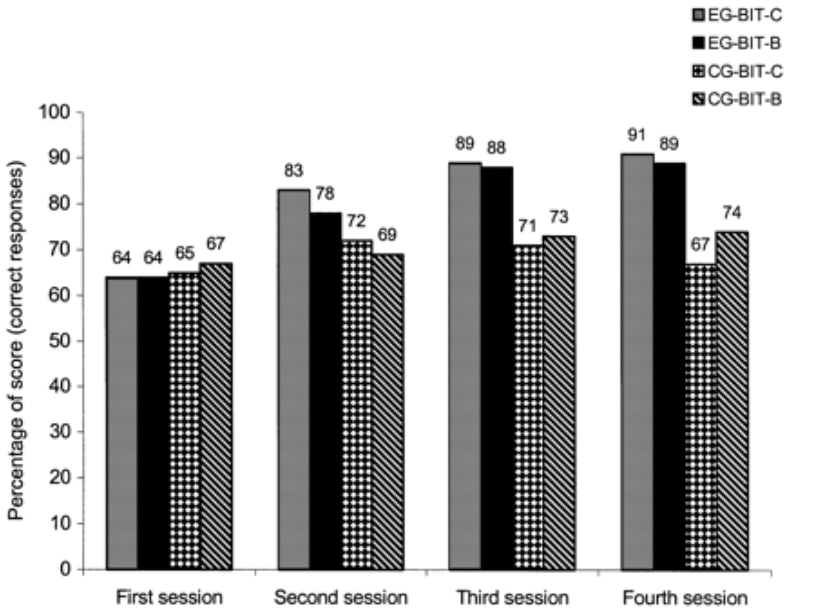
Rightward displacing prisms produce a leftwards after effect
- this reflects an adaptive realignment of the internal visual and proprioceptive 'maps'



Parton *et al* (2004) *JNNP*

Bursts of prism therapy lead to long-lasting improvements in left neglect

Performance on BIT neglect battery

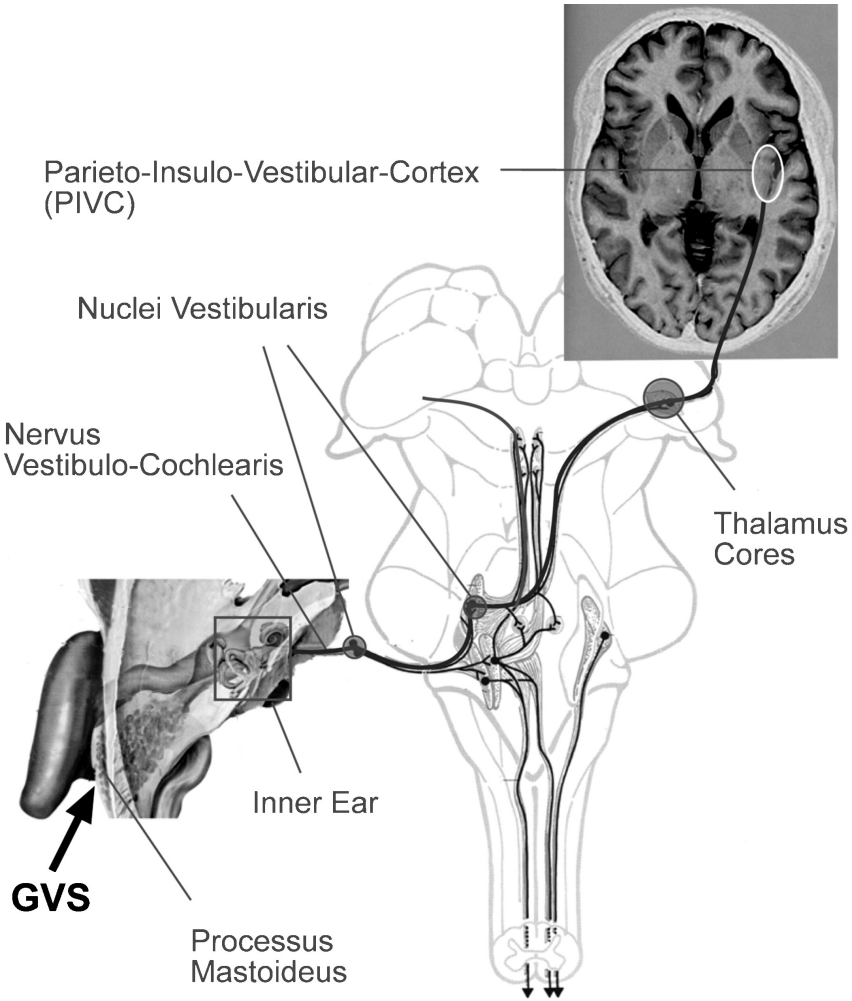


Experimental group (n=7)

Control group (n=6)

Frassinetti et al. Brain 125: 608

Galvanic vestibular stimulation



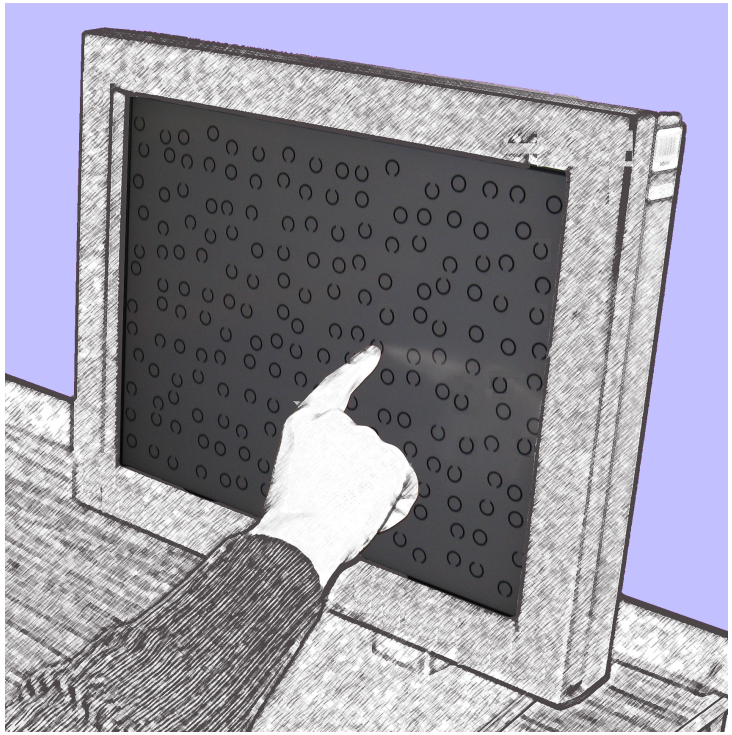
Treating non-spatially lateralised deficits
(ie those that effect both sides of space)

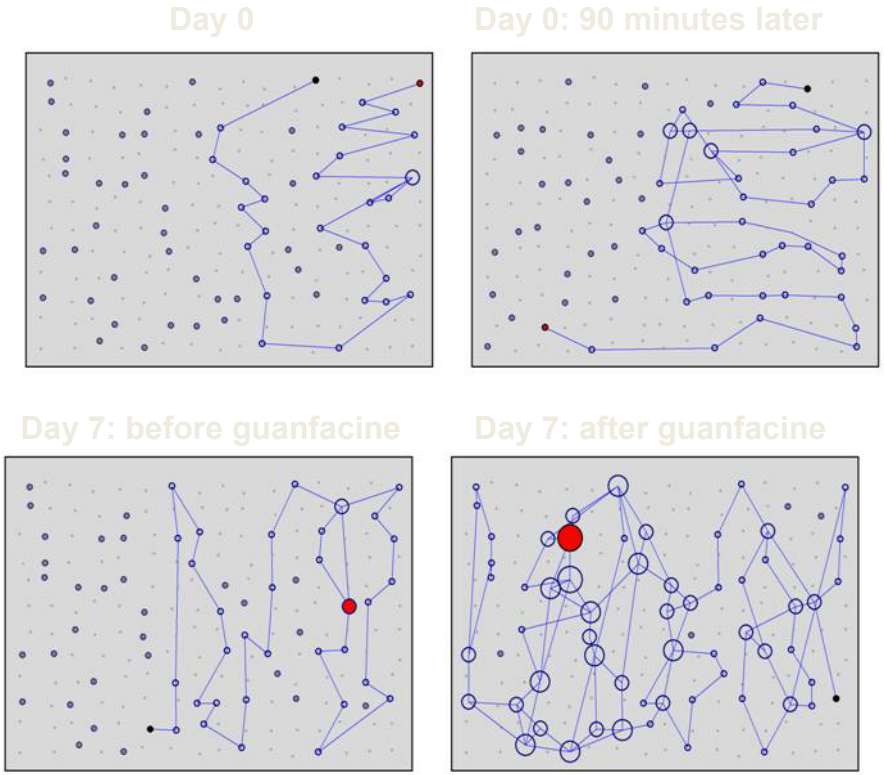
Behavioural

- Increasing patients alertness - tone before stimulus presentation
- Tasks that required sustained attention eg sorting coins or cards

Targeted pharmacological interventions

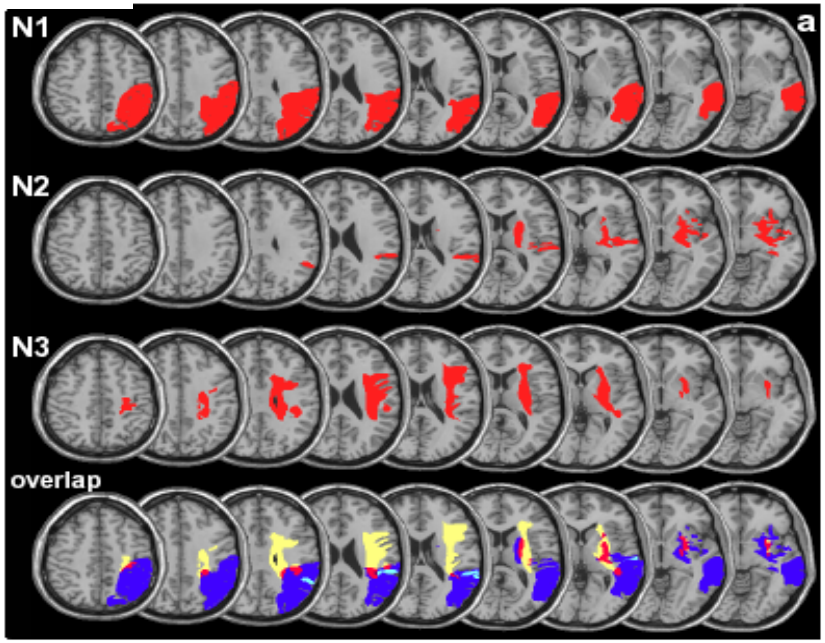
Guanfacine, an alpha-2 noradrenergic agonist, improved space exploration in neglect patients without extensive prefrontal damage

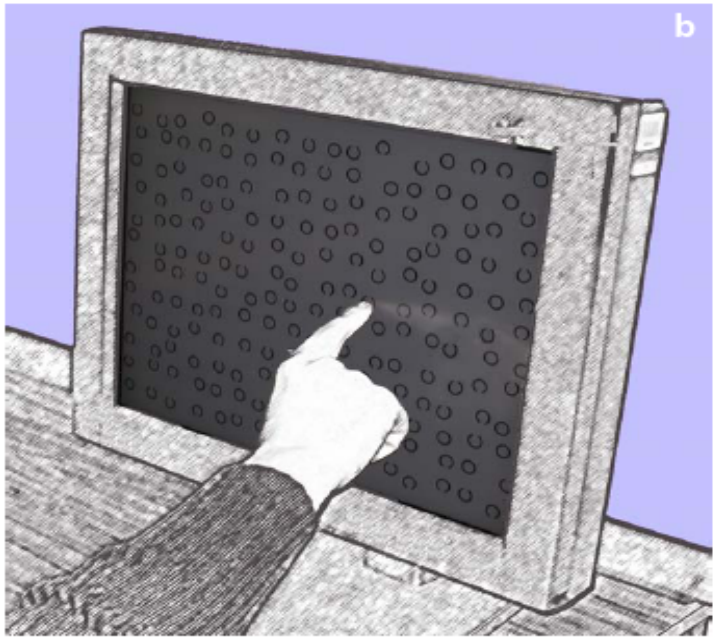


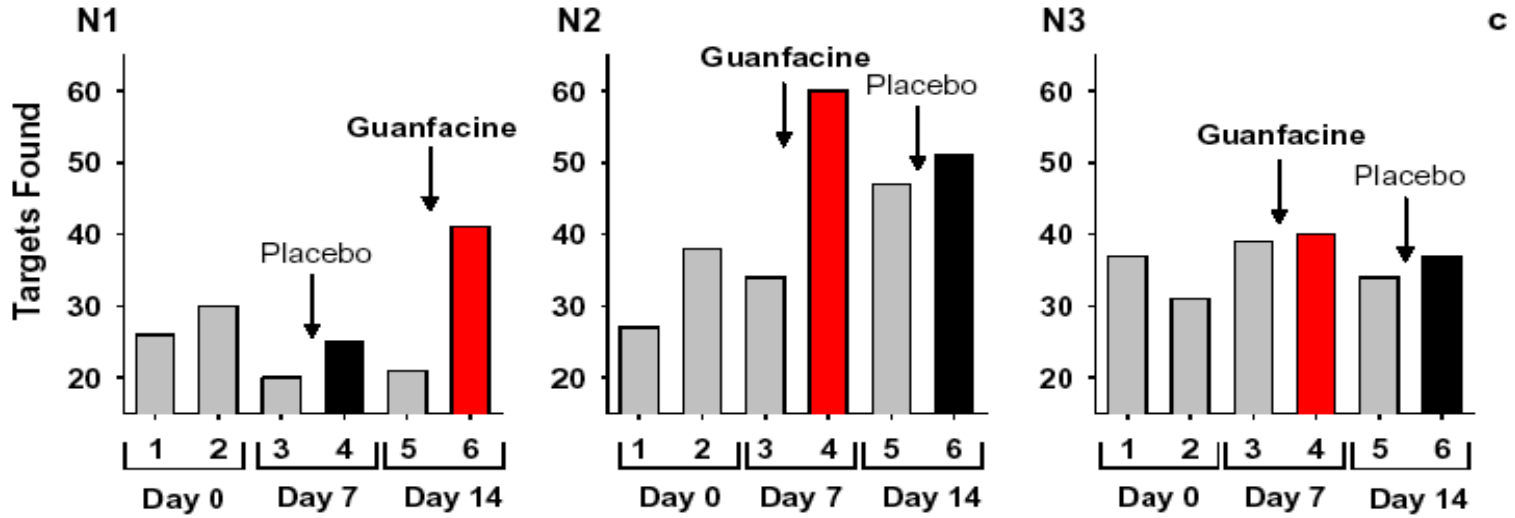


Guanfacine was associated with better exploration of leftward space, increasing the time that patients sustained attention on the task

Malhotra *et al* (2006) *Ann Neu*


N1
N2
N3
overlap
a


b


N1
N2
N3
c
Targets Found
60
50
40
30
20
Guanfacine
Placebo
1
2
3
4
5
6
Day 0
Day 7
Day 14

Conclusions

- The evidence base for the successful rehabilitation of both homonymous field defects and hemi-spatial neglect is still weak
- Many of the studies have been poorly controlled or the numbers of subjects have been inadequate
- However, for HH defects saccadic training methods may provide some benefit and are cheap and accessible in the patients home
- As our understanding of the different mechanisms giving rise to visuo-spatial neglect improve, so will the development of new innovative treatment strategies