Homonymous Hemianopia

Impact on Daily Life and the Effects of Scanning Training on Mobility

Gera A. de Haan

The research described in this thesis was supported by:
ZonMw - InZicht (project 94307005)
The Heymans Institute, University of Groningen
Royal Dutch Visio (project OI0204)
School of Behavioral and Cognitive Neuroscience (BCN), University of Groningen
Centraal Bureau Rijvaardigheidsbewijzen (CBR)
Bartiméus

Printing of this thesis was financially supported by:
Royal Dutch Visio
University of Groningen
School of Behavioral and Cognitive Neuroscience (BCN), University of Groningen
Bartiméus

Cover: Elbrich Steegstra - Grafisch Ontwerp en Illustratie
Printed by: Gildeprint - Enschede

ISBN 978-90-367-9089-5 (printed version)
ISBN 978-90-367-9086-4 (electronic version)

rijksuniversiteit groningen

Homonymous hemianopia

Impact on daily life and the effects of scanning training on mobility

Proefschrift

ter verkrijging van de graad van doctor aan de
Rijksuniversiteit Groningen
op gezag van de
rector magnificus prof. dr. E. Sterken
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

donderdag 27 oktober 2016 om 14.30 uur

door

Gera Ada de Haan

geboren op 15 december 1987
te Zwolle

Promotores
Prof. dr. W.H. Brouwer
Prof. dr. O.M. Tucha

Copromotores
Dr. J.H.C. Heutink
Dr. B.J.M. Melis-Dankers

Beoordelingscommissie
Prof. dr. J.M. Spikman
Prof. dr. G. Kerkhoff
Prof. dr. J. van der Steen

CONTENTS

1

General introduction

HOMONYMOUS VISUAL FIELD DEFECTS

Damage to the brain may have significant implications for everyday life. As a consequence of brain damage, people may, depending on the site of lesion, lose certain parts of their visual field. This is explained in Figure 1.1. Visual information is transported along the nerves running from the eyes through the brain to the primary visual cortex. Part of these nerves cross at the optic chiasm. This way, information from the left side of the visual field (left hemifield) is processed in the visual cortex of the right hemisphere and vice versa. In case of damage posterior to the optic chiasm, the visual field defect is contralateral and similar for both eyes (homonymous). Such an area of cortical blindness due to contralateral postchiasmatic brain damage is generally referred to as a homonymous visual field defect (HVFD). Depending on the size and location of the brain damage, the visual field defect can appear as a hemianopia (half of the visual field affected), quadrantanopia (quarter of the visual field affected), scotoma (smaller part of the visual field affected) or any form in between. It has been estimated that homonymous hemianopia (HH), the most common form of HVFD, occurs in 8–31% of all stroke patients (Feigenson, McCarthy, Greenberg, & Feigenson, 1977; Gilhotra, Mitchell, Healey, Cumming, & Currie, 2002). HVFD can also be the result of traumatic brain injury, brain tumor, or other pathologies such as multiple sclerosis, epileptic disorders, and the posterior form of Alzheimer disease (Trobe, Lorber, & Schlezinger, 1973; Zhang, Kedar, Lynn, Newman, & Biousse, 2006a). Although full or partial recovery of the visual field occurs for some persons, often a visual field defect remains (Ali et al., 2013; Pambakian & Kennard, 1997; Zhang, Kedar, Lynn, Newman, & Biousse, 2006b).

Since only part of the visual field is perceived in case of HVFD, a complete overview of the surroundings is less easily obtained. By shifting the gaze towards the blind side, new information is perceived. However, people with HVFD often make insufficient and small saccades towards the blind side (Tant, Cornelissen, Kooijman, & Brouwer, 2002), supposedly because there is no information coming from the field defect grasping their attention. This causes scanning to be inefficient and time consuming. Especially when moving around, information from the periphery is important; it is essential for orienting and navigating, and provides warning signals about other people or vehicles approaching from the side. If mobility is restricted, this might lead to social isolation, depression, and decreased quality of life (Gall, Franke, & Sabel, 2010; Papageorgiou et al., 2007; Wagenbreth, Franke, Sabel, & Gall, 2010).

REHABILITATION OF HVFD

Fortunately, more and more rehabilitation programs for people with HVFD are being developed and tested. Programs aimed at minimizing the impact of the visual field defect by changing either patient behavior or the environment are known as compensatory programs. In 1979, Johnson and Cryan (1979) were the first to provide exercises that may be used to improve compensatory scanning behavior (i.e., adaptations in the use of eye movements). They emphasized the importance of improving the patient's awareness and understanding of the HVFD. Later, numerous different compensatory scanning training (CST) programs have been developed, of which an overview is provided in chapter 6. In the Netherlands, CST programs started to be provided two decades ago at Royal Dutch Visio (location Haren), a center of expertise for blind and partially sighted people. Since then, the requests for

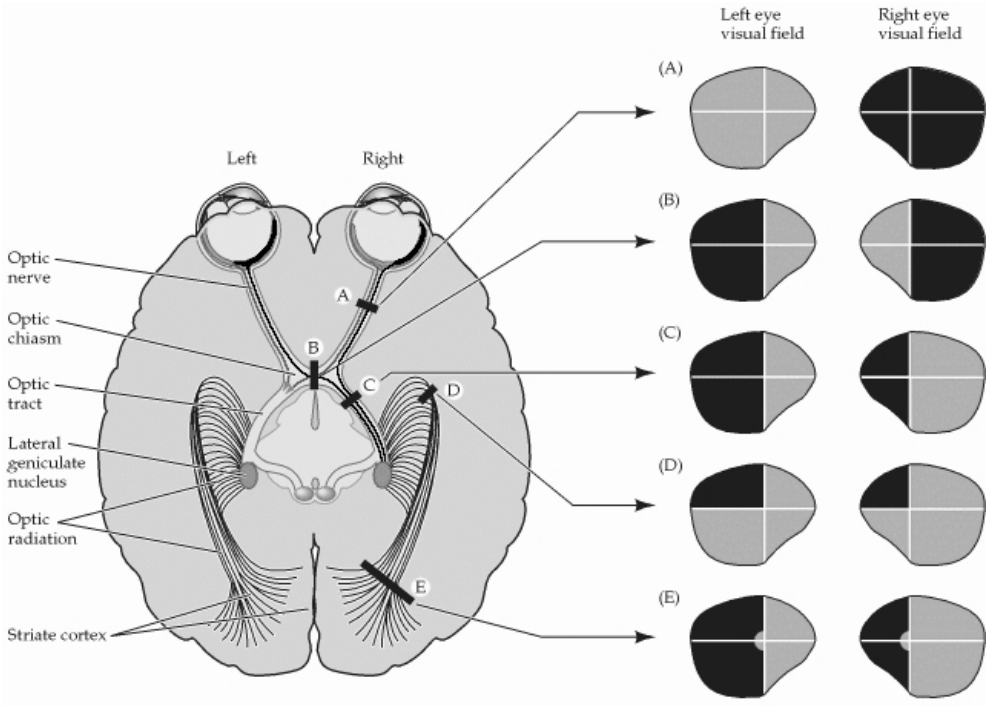


Figure 1.1. Neuro-anatomy of the main visual pathways from the eyes to the primary visual cortex (striate cortex). The black parts in the figures on the right represent the affected parts of the visual field as a result of brain damage at different locations (A-E). Reprinted with permission (slight modifications added) (Purves et al., 2001).

compensatory training by people with HVFD have increased. However, standardized protocols for CST are not widely available and there is a considerable variety in approaches, rationales and training exercises among the different CST programs.

Besides training focusing on compensation, two other approaches to the rehabilitation of HVFD exist: restorative training and use of prism glasses. Restorative training is devoted to enlargement of the visual field itself and requires intensive training. Prisms glasses are aimed at shifting part of the information from the blind side into the intact visual field. However, this shifting of information inevitably leads to a certain degree of image distortion. There is insufficient evidence from scientific studies for the effects of both of these approaches (Bouwmeester, Heutink, & Lucas, 2007; Pollock et al., 2011; Reinhard et al., 2005). As pointed out by systematic reviews, previous studies on the effects of CST have been encouraging, but the impact on activities of daily living is unclear (Bouwmeester et al., 2007; Kerkhoff, 1999; Pollock et al., 2011). This lack of evidence is likely to be a result of the following factors: In many effect studies, part of the tests used to assess the effect of training tended to be very similar to the exercises practiced during training. Very few studies incorporated mobility-related effect measurements. Only little evidence has been found for transfer of CST effects to

activities of daily life beyond the specific tasks that were trained. Furthermore, the majority of these studies used within-subjects designs. A few randomized controlled trials (RCTs) have been performed comparing the effects of CST with a control group (Aimola et al., 2014; Lane, Smith, Ellison, & Schenk, 2010; Moedden et al., 2012; Roth et al., 2009; Schuett, Heywood, Kentridge, Dauner, & Zihl, 2012), but only for CST programs with a focus on searching for a target in an array with distractors. In conclusion, a well-designed study on the effects of CST on mobility-related activities and participation in society is needed in order to enable evidence-based training for improving orientation and mobility in daily life.

THESIS OUTLINE

This thesis focuses on the consequences of having HVFD for everyday life, and more specifically, for mobility-related activities and participation. Four main issues will be addressed: the focus of previous studies on HVFD, the functioning of patients with HVFD, the effects of training, and the factors that influence functioning or training effects. **Chapter 2** describes the design and setup of our study on HVFD. An overview of 221 scientific publications on HVFD is provided in **chapter 3**. This review summarizes what has been examined in previous studies and what factors have been found to influence functioning of HVFD patients or treatment effects. **Chapter 4** is devoted to the difficulties that 54 participants with HVFD reported to experience in daily life. **Chapter 5** presents the results of a study on car driving performance in a subgroup of 26 participants, as assessed with an official on-road test of practical fitness to drive by the Dutch driver's licensing authority. We examined how driving performance was affected by HVFD and which participant characteristics were related to driving performance. **Chapter 6 and 7** present the results of the RCT that examined the effects of the IH-CST (Insight-Hemianopia Compensatory Scanning Training) on a wide range of mobility-related outcome measures. In the study presented in **chapter 6**, it was first examined how participants with HVFD performed on scanning and mobility-related measures before onset of training in comparison with a healthy control group. Then the effects of IH-CST were studied by comparing performance before and after training with performance of patients in a waiting list control group. In the study presented in **chapter 7**, the within-group training effects were examined in an extended patient group and it was examined to what extent training effects were still present after a period of six to ten months following treatment. It was also investigated to what extent performance of the patients after training approached the level of performance of the healthy control group. Furthermore, it was studied whether it could be predicted beforehand which patients benefit from IH-CST most. A general discussion of the preceding chapters, implications for clinical practice, and suggestions for future research are provided in **chapter 8**.

2

Study design

Preceding the empirical study that is described in this chapter, the literature on homonymous visual field defects (HVFD) was reviewed. The setup and results of this review are provided in chapter 3.

PROJECT COLLABORATION

The findings presented in chapter 4 to 7 of this thesis result from a study on a group of people with HVFD in the Netherlands, performed between 2009 and 2014. For this study, the University of Groningen closely collaborated with Royal Dutch Visio and Bartiméus, the two largest Dutch centers of expertise for blind and partially sighted people, as well as with the CBR (Centraal Bureau Rijvaardigheidsbewijzen; the Dutch driver's licensing authority). The project *InZicht Hemianopsie* (IH) was set up to organize the actions necessary to perform the study, managed by the so-called *IH project group* (Joost Heutink, Bart Melis-Dankers and Gera de Haan). The IH project group had frequent meetings with the management teams of Visio and Bartiméus. Instructions were written for admission workers, planning departments, optometrists, orthoptists, neuropsychologists and occupational therapists. The colleagues of Visio and Bartiméus that collaborated in the project formed local *IH-teams*, coordinated by the local neuropsychologists. Letters were sent to referring doctors (eye doctors, neurologists and doctors specialized in rehabilitation) to inform them about the new training program being available for patients with HVFD and about the study being performed. Agreements with the CBR were made on how to integrate the official relicensure procedure into our study (see 2.4.2). Based on the results of the current study, reports were sent to Visio, Bartiméus and the CBR.

RECRUITMENT OF PARTICIPANTS

Participants were recruited from Visio and Bartiméus. All 17 locations of the Rehabilitation department of Visio and one location of Bartiméus participated in the project. The so-called *inclusion phase* (see Figure 1.2) covered the following steps. All patients with HVFD or suspected HVFD that applied for help at these centers were informed about the study by the admission workers. During the admission interview, a questionnaire was administered that was specially designed for this study. Using the information from this questionnaire as well as the medical record, members of the IH project group evaluated whether the Insight-Hemianopia Compensatory Scanning Training (IH-CST) would fit the needs and possibilities of the patient. Based on a set of predefined in- and exclusion criteria, it was decided whether the patient could be preliminary included in the study. In case the patient passed the first round of inclusion, information about the study was sent to the patient along with an informed consent form. Patients that decided not to participate in the study could still receive the IH-CST at Visio or Bartiméus. In case of informed consent, standardized assessments of visual and neuropsychological functions were performed at Visio or Bartiméus. Special protocols for these assessments were developed by the IH project group, assuring a similar way of testing for each patient. Based on the results of these assessments, the IH project group decided whether the patient was included in the study. In case of inclusion, the IH project group, the planning department of Visio or Bartiméus and the patient together scheduled the appointments for the IH-CST and effect measurements. Healthy control participants without visual or neurological

disorders were recruited via public announcements. They were matched with the patient group on age and level of education.

TRAINING

More information on the IH-CST is provided in chapter 6. The full training protocol is available at Visio and Bartiméus for occupational therapists trained for applying the protocol. The training protocol is an adaptation of the training programs of Pizzamiglio (Pizzamiglio et al., 1992), Kerkhoff (Kerkhoff, Munssinger, Haaf, Eberlestrauss, & Stogerer, 1992; Kerkhoff, Munssinger, & Meier, 1994) and Tant (2002). This adaptation was performed, in consultation with members of the IH project group, by two occupational therapists from Visio in Haren (Birgit van Iddekinge and Marie-Louise Kamps) based on years of experience with teaching compensatory eye movements to patients with HVFD. The training is abbreviated as IH-CST, short for InSight-Hemianopia Compensatory Scanning Training, but better known as the *IH-training*.

The aim of the IH-CST is to teach patients with HVFD to compensate for their visual field defect during a wide range of mobility-related activities. Early detection of obstacles is of high importance during mobility. When an obstacle is detected, one can react on this in time in order to avoid collision. The compensation strategy taught in the IH-CST is to apply a scanning rhythm consisting of a triad of saccades. First, a large saccade towards the blind side is made, in order to receive information from the periphery. This is followed by a second saccade back towards the seeing side to prevent overcompensation. Third, a small saccade is made back to the starting point of looking straight forward. Patients learn to generate this scanning rhythm endogenously on an anticipatory basis. Speed of repetition of the scanning rhythm is adapted to environmental demands and speed of moving around. The ultimate goal is to improve participation in society and vision-related quality of life.

The training program consists of exercises for improving awareness of the visual field defect and its consequences for daily life, exercises to learn the scanning rhythm, and practice of the scanning rhythm in daily life mobility situations. The default schedule is set at 15 individual sessions of 60–90 minutes each, 18.5 hours of face-to-face training in total during a period of 10 weeks. Most important, however, is that the patient proceeds to the next exercise once the predefined targets of an exercise are accomplished. This creates flexibility for individual needs and progress and can cause the training to take less or more than 15 sessions.

Thirty occupational therapists from Visio and Bartiméus experienced in working with brain injured patients were schooled in providing the IH-CST to patients with HVFD. Using a train-the-trainer model, these therapists followed complementary theoretical and practical in-service education on the IH-CST protocol, provided by the occupational therapists that had developed the protocol. This was monitored by members of the IH project group, who also provided further information on HVFD and the setup of the study.

New software was needed in order to implement the exercises as drafted by the occupational therapists into the training program. This software was developed by the faculty of Behavioral and Social Sciences of the University of Groningen. The training materials were installed by the IH project group at nine locations of Visio and one location of Bartiméus. This minimized traveling distance for the patients. Furthermore, this made that the effects of

training could not be ascribed to the expertise of occupational therapists in one region only.

DESIGN AND DATA COLLECTION

Assessments T1, T2, T3 and FU

In order to examine the effects of IH-CST, participants were assessed before and after training (Figure 1.2). The study design was organized as a randomized controlled trial (RCT), comparing a group that received training (training group) with a group that did not (waiting list control group). This way, the design allowed controlling for spontaneous improvements and testing effects. Once patients were included for participation in the study, they were assigned to either the training group or the waiting list control group using the method of minimization, which is further described in chapter 6. Participants in the training group were assessed the week before training (T1) and again after 15 training sessions (T2). Patients in the waiting list control group received no training between T1 and T2, and followed 15 training sessions between T2 and T3. Both groups thus received the same IH-CST, but at a different time in their trajectory. Time between two assessments (i.e., between T1 and T2 and between T2 and T3) was 13 weeks. Six to ten months after the last assessment, a follow-up assessment (FU) was performed for both groups.

Training effects were assessed on several vision-related body functions and activities, as well as on participation in society (Table 2.1). Effect measurements included on-line measurement of eye movements, basic visual scanning tasks, scanning tasks with high ecological validity, mobility tasks, a driving simulator, and self-reported mobility performance and vision-related quality of life. The following chapters in this dissertation describe the results of analyses on part of these data. For the analyses described in chapter 4, data are used from T1 of both patient groups. In chapter 6, data from T1 and T2 in the training group are compared to data from T1 and T2 in the waiting list control group. In chapter 7, the within group effects of training (T-pre to T-post) are discussed by merging the data of the training group (T1 and T2) and the waiting list control group (T2 and T3). Chapter 7 also includes the data from the FU assessment and data from neuropsychological testing during the inclusion phase and T1.

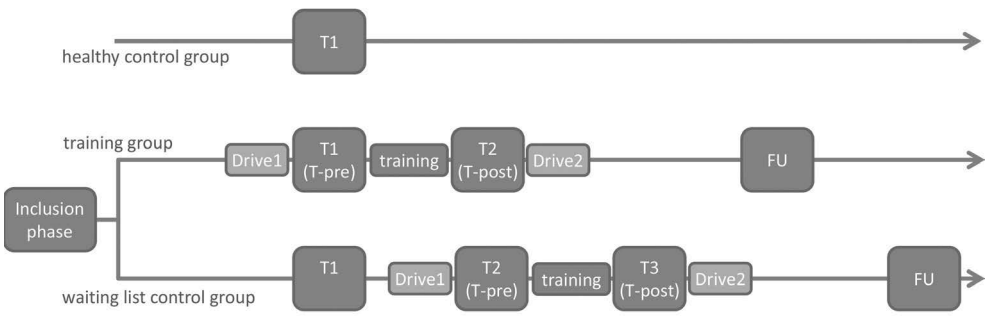


Figure 2.1. Study design.

Table 2.1. Overview of tests administered on assessments T1, T2, T3 and FU.

		T1			T2		T3	FU
		Healthy control group	Training group	Waiting list control group	Training group	Waiting list control group	Waiting list control group	All patients
Neuropsychological tests [a]	Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975)	V						
	Digit Span (WAIS subtest) (Wechsler, 1997)	V	V	V	V	V	V	
	Zoo Map (BADS subtest) (Wilson, Alderman, Burgess, Emslie, & Evans, 1996)		V	V				
	15 Word Test (Saan & Deelman, 1986; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2005)		V	V				
	Nederlandse Leestest voor Volwassenen (Schmand, Lindeboom, & Van Harskamp, 1992)		V	V				
	Grey Scales (Mattingley et al., 2004; Tant, Kuks, Kooijman, Cornelissen, & Brouwer, 2002)		V	V	V	V	V	
Tests for visual functioning	ETDRS letter chart (acuity) [b]	V	V	V	V	V	V	
	GECKO (contrast sensitivity) [b]		V	V	V	V	V	
	Goldmann (visual field) [b]		V	V	V	V	V	
Reading tests	Radner reading chart [b]		V	V	V	V	V	
	Standardized reading text [b]		V	V	V	V	V	
Scanning tests	Dot counting test [b]	V	V	V	V	V	V	
	Visual search test [b]	V	V	V	V	V	V	
	Hazard perception test [b]	V	V	V	V	V	V	
Dynamic tests	Tracking Task [b]	V	V	V	V	V	V	
	Obstacle course [b]	V	V	V	V	V	V	
	Driving simulator [c]				V	V	V	
Questionnaires	Motivation questionnaire [d]		V	V		V		
	Evaluation questionnaire [e]				V		V	V
	Insight questionnaire [f]		V	V	V	V	V	

	T1			T2		T3	FU
	Healthy control group	Training group	Waiting list control group	Training group	Waiting list control group	Waiting list control group	All patients
Life events questionnaire [g]		V	V	V	V	V	V
NEI-VFQ-25 [b]		V	V	V	V	V	V
IMQ [b]		V	V	V	V	V	V
CVD [b]		V	V	V	V	V	V
Car driving							V

[a] The neuropsychological test results give an indication for cognitive functions, premorbid intelligence and visual hemi-inattention. These functions might be related to training effect (chapter 7). The Digit Span is also administered for determining the difficulty of the cognitive task during the walk through the obstacle course.

[b] Test is described in chapter 6.

[c] Driving performance is assessed in a driving simulator in diverse, but standardized situations and at various speeds (Brouwer, Busscher, Davidse, Pot, & Van Wolffelaar, 2011; Piersma et al., 2016). For logistic reasons, these rides were only administered at T2 and not at T1, allowing comparison between patients who have received training and patients who have not. Only the patients in the waiting list control group that participated in the relicensure procedure performed the rides again at T3. This should enable us to examine the associations between simulated and on-road driving performance (data not analyzed yet).

[d] Questions were selected by author from the Motivation for Traumatic Brain Injury Rehabilitation Questionnaire (Chervinsky et al., 1998).

[e] Evaluation questionnaire was developed by author of this thesis based on evaluation questionnaires from the Rehabilitation Center UMCG-Beatrixoord.

[f] Insight questionnaire was developed by author of this thesis based on theories on awareness by Crosson (Crosson et al., 1989) and Critchley (Critchley, 1949) and piloted in a group of patients with hemianopia.

[g] Questions were selected by author of this thesis from the Life Events Questionnaire (Norbeck, 1984).

[h] Car driving questionnaire was developed by author of this thesis in order to examine the self-reported effects of training on car driving performance.

Driving tests

In the Netherlands, people with HVFD are not allowed to drive a car, unless the CBR has explicitly decided one is practically fit to drive. A subgroup of the participants applied for help with regaining a valid drivers' license and followed a relicensure procedure parallel to their participation in the current study. The University of Groningen, Visio and the CBR collaborated in order to adjust the trajectories and to examine the effects of IH-CST on car driving. During the inclusion phase, the IH project group and the CBR together evaluated whether these patients met the legal criteria for car driving, based on the results of the standardized visual and (neuro)psychological testing at Visio (see Table 2.2). When this was confirmed, the patient performed an official on-road driving test for evaluation of practical fitness to drive by a driving expert of the CBR. This driving test took place shortly before onset of the IH-CST (1-12 days before T-pre, see Figure 1.2). In case the patient was rated unfit to drive, a second driving test was allowed after following the IH-CST and, if necessary, following a number of driving lessons at one of the driving schools that had received additional education from Visio and the CBR on visual impairments. The driving expert rated driving performance using a standardized scoring form and gave an end-verdict on practical fitness to drive (i.e., fit or unfit). These data were

provided for further analysis as part of the study (Table 2.2). More information on the procedure and results of the first driving tests is provided in chapter 5.

Other data

The healthy control group had completed a questionnaire before they were included and these data were processed as well (date of birth; gender; level of education, self-reported ocular, physical and psychological disorders, driving experience and current driving behavior). In case a patient was included for participation in the assessments, data from the inclusion phase were collected (Table 2.2). During the individual training trajectories, information on the progress of the patient was registered. The standardized forms as completed by the occupational therapists were summarized by one of the therapists involved in the development of the training protocol (Birgit van Iddekinge). This informed us about compliance with the training protocol (Table 2.2). At the end of the data collection, the occupational therapists providing the IH-CST to the participants were asked to evaluate the training protocol. On five-point rating scales, they rated several aspects of feasibility, efficacy and instruction quality of the IH-CST, and provided suggestions for improvement.

Table 2.2. Overview of patient data collected during the inclusion phase, training and driving tests.

Source	Data
Inclusion phase:	• Admission questionnaire (self-reported vision-related complaints, level of education, left or right hand preference, impairments restricting mobility other than visual impairment (e.g. physical, hearing or panic disorders), and history of psychological treatment; questions on medication, smoking, alcohol, and drugs; impression of insight by the admission worker) • Assessment of visual functions (visual acuity [ETDRS letter chart at 4m 500lux], refraction, reading acuity [LEO reading chart], visual fields [peripheral perimetry: standardized Goldmann; central perimetry: Humphrey 10-2 or equivalent], contrast sensitivity [Vistech], eye and head motility, image distortion [Amsler]) • Neuropsychological testing (Mini Mental State Examination (Folstein et al., 1975), Visual Object and Space Perception Battery (Warrington & James, 1991), Balloons Test (Edgeworth, Robertson, & McMillan, 1998), 8 Word Test (Lindeboom & Jonker, 1989), Trailmaking Test A and B (Reitan, 1958), Line Bisection (Schenkenberg, Bradford, & Ajax, 1980), Complex Figure of Rey (Meyers & Meyers, 1995), Hospital Anxiety and Depression Scale (Spinhoven et al., 1997), drawings, tests for optical ataxia and oculomotor apraxia) • Demographic data (e.g. date of birth, gender) • Medical records (e.g. etiology, date of onset) • AutO&Mobility questionnaire when patient applied for help with the relicensure procedure (e.g. self-reported medical situation, medication, driving experience, current driving behavior, state of driver's license)
Training:	• Evaluation of exercises and progress by the therapist (standardized forms) • Data from training software • Diary of homework assignments
Driving tests:	• TRIP checklist (Appendix 5.1) • End verdict (fit or unfit to drive) • Written report on driving performance (unstandardized)

3

Spontaneous recovery and treatment effects in patients with homonymous visual field defects: a meta-analysis of existing literature in terms of the ICF framework

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Tucha, O., & Brouwer, W. H. (2014). Spontaneous recovery and treatment effects in patients with homonymous visual field defects: a meta-analysis of existing literature in terms of the ICF framework. *Survey of Ophthalmology, 59*(1), 77-96.

ABSTRACT

Homonymous visual field defects (HVFDs) are a common consequence of posterior brain injury. Most patients do not recover spontaneously and require rehabilitation. To determine whether a certain intervention may help an individual patient, it is necessary to predict the patient's level of functioning and the effect of specific training. We provide an overview of both the existing literature on HVFDs in terms of the International Classification of Functioning, Disability, and Health (ICF) components and the variables predicting the functioning of HVFD patients or the effect of treatment. We systematically analyzed 221 publications on HVFD. All variables included in these articles were classified according to the ICF, as developed by the World Health Organization, and checked for their predictive value. We found that ICF helps to clarify the scope of the existing literature and provides a framework for designing future studies, which should consider including more outcome measures related to Activities and Participation. Although several factors have been described that predict HVFD patients' level of functioning or the effects of training, additional research is necessary to identify more.

INTRODUCTION

Among the most common consequences of postchiasmatic stroke are homonymous visual field defects (HVFDs), such as hemianopia. These often have a negative impact on the patients' level of functioning. There is an increasing amount of attention to the possibilities of treatment, which is either aimed at restoration of the visual field or at compensation for the field defect. Although there are analyses of the factors that predict the level of functioning for patients with HVFDs or the effect of an intervention, to our knowledge there has been no large-scale review. Furthermore, most studies on HVFDs make use of a myriad of parameters, and consistency in measurements among the different studies is lacking. To create an accessible overview of the information in the available literature, all individual parameters described in 221 articles on HVFD were classified and examined for their predictive effect on other parameters.

We use the International Classification of Functioning, Disability, and Health (ICF). The ICF, as developed by the World Health Organization in 2001, has the purpose of establishing a common language for describing health and health-related states in order to improve communication among users such as health care workers, researchers, policymakers and the public, including people with disabilities (World Health Organization, 2001). The ICF framework (Figure 3.1) consists of two parts outlining the situation for a patient with a given health condition. The first describes Functioning and Disability and distinguishes the components *Body Functions and Structures* and *Activities and Participation*. The second part, the Contextual Factors, consists of the components *Environmental Factors* and *Personal Factors*. The Body Functions not only include physiological, but also psychological, functions, whereas the Body Structures describe anatomical body parts. The ICF defines an Activity as "execution of a task or action by an individual" which represents "the individual perspective of functioning." Participation is defined as "a person's involvement in a life situation," which represents "the societal perspective of functioning." Functioning and Disability can be influenced by external Environmental Factors, such as the physical and social environment of an individual, as well as by internal Personal Factors, the characteristics of the individual. The components are further structured in domains and categories, resulting in unique codes for individual parameters.

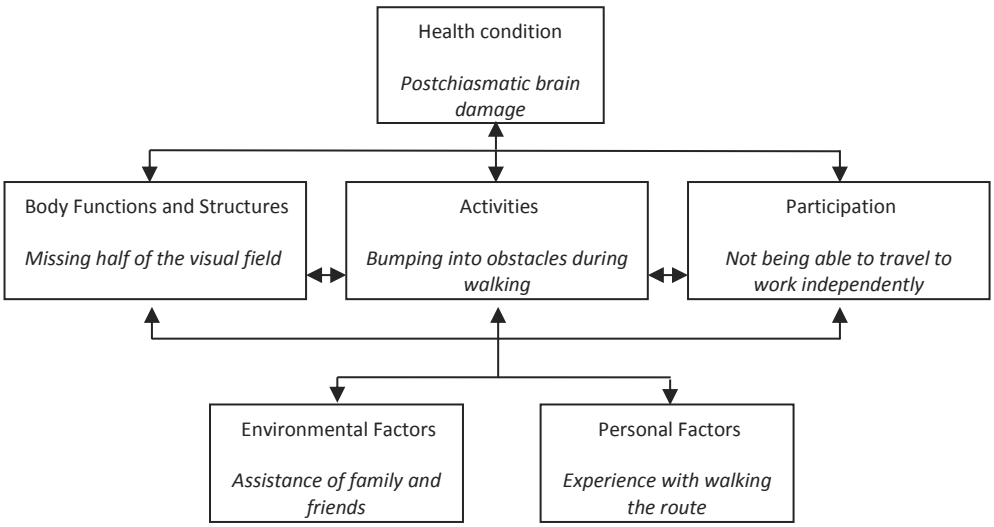


Figure 3.1. An illustrative example of the ICF scheme (World Health Organization, 2001) in case of homonymous hemianopia, a common form of HVFD.

The ICF as widely used in rehabilitation settings helps the clinician decide which levels of functioning should be assessed. For example, in case of a patient with postchiasmatic brain damage (Health Condition), the visual field (Body Functions) could be assessed, as well as the degree of bumping into objects (Activities) and the difficulty traveling to work (Participation). Furthermore, the impact of Environmental Factors, such as social support from family and friends, as well as Personal Factors, such as the patient's experience with walking the route to work, are worth being assessed, because they can have a large influence on the functioning of the patient (see Figure 3.1).

The wide application of the ICF in rehabilitation settings makes the ICF a suitable framework for examining how the components of interest for clinical rehabilitation are examined and described by the existing research literature. We apply the ICF to gain more insight into the HVFD, which refers to blindness for part of the visual field caused by postchiasmatic brain damage. Because of the location of the injury, the visual field defect is identical for both eyes and therefore is called homonymous. HVFD is a negative predictor for recovery after stroke. When stroke patients also have HVFD, they require longer rehabilitations in hospitals, are less independent in their mobility, have a lower rate of independence in self-care function, and are more impaired in their activities of daily life (Feigenson et al., 1977; Friedman, 1995; L. Han, Law-Gibson, & Reding, 2002; Patel, Duncan, Lai, & Studenski, 2000; Reding & Potes, 1988).

Only in a minority of cases does the visual field completely recover spontaneously, although the literature is ambiguous about the exact numbers (Zihl, 2011). For patients with persistent field defects, several training methods are available. One approach is restorative training, which is aimed at regaining visual functions at the border of or within the field defect,

and therefore its focus is on the ICF component Body Functions and Structures. Another approach is compensatory training, aimed at learning how to deal with the field defect. Compensatory training usually focuses on making systematic eye movements, although there is a large variance in training protocols used (for an overview see Bouwmeester, Heutink and Lucas (2007). Whereas some protocols teach patients to make systematic eye movements during exploration tasks, others focus on specific eye movements during reading. We include the use of prism glasses in our discussion of compensatory treatment. For compensatory training, the outcome can also be on a Body Function, but often improvement on Activities and Participation, such as improvement in the mobility domain, is the aim of compensatory treatment. There has been a substantial amount of discussion on whether the restorative training truly restores the visual field or if the effects could be confounded by unsteady fixation during perimetry assessment (Bouwmeester et al., 2007; Pollock et al., 2011; Reinhard et al., 2005).

From a rehabilitation perspective, it is important to be able to assess prognosis and to choose the right intervention for a patient with HVFD. When it is known which factors influence a patient's level of functioning, this increases knowledge of the characteristics that predict the development of the field defect, level of future functioning, and the effect of treatment. For example, when it is not expected that restorative training will improve the visual field any further, the patient could possibly still benefit from compensatory training.

We review the literature on HVFD within the scope of the ICF to give an overview of the existing literature on HVFDs in terms of the ICF components and the variables predicting the functioning of HVFD patients or the effect of treatment. First, HVFD and its relationship with the different ICF components are described in more detail. Second, the ICF scheme is applied to systematically categorize all variables studied, as well as the specific predictors analyzed by the selected literature. The results section includes an overview of the focus in terms of the ICF of all variables examined in the literature (Table 3.1), of the predictors (Tables 3.1 and 3.3) and of the predictor-outcome combinations (Table 3.2). At last, the most relevant factors found to predict the HVFD patients' level of functioning and the effects of treatment are described (section 3.4.2). We hope that this review will allow clinicians, as well as researchers, to select from ICF components of interest, from several specific parameters, or from information on restorative training, compensatory treatment, or no treatment.

HVFD AND ITS RELATION TO THE ICF COMPONENTS

HVFD: different types and their frequencies of occurrence

HVFD is classified in the ICF under *Body Function b210: Seeing functions*, and more specifically under *b2101: Visual field functions* (World Health Organization, 2001). HVFDs depend on the size and location of the postchiasmatic brain lesion. In a complete hemianopia, half of the visual field is absent, and in a quadrantanopia only a quarter of the visual field is missing. In cases of macular sparing, the central visual field is spared. In case of a partial defect, the visual field defect is called a scotoma, although in some traditions, scotoma is actually used as the general term for different types of visual field defects, including hemianopia. The terms hemianopia and HVFD are often used for the same field defects, although hemianopia does not necessarily imply a homonymous field defect, and HVFDs do not have to be restricted to one-

half of the visual field. We use the term HVFD to refer to visual field defects that are homonymous and mainly restricted to one half of the visual field. Other patterns of visual field defects exist, such as bitemporal and altitudinal and other monocular field defects, but because the underlying pathology of these defects is prechiasmatic, and the consequences for daily life are also different, these fall outside the scope of the present review.

Several authors mentioned the frequencies of different forms of HVFD. It is often assumed that the type of field defect has an influence on the level of functioning, as is further illustrated in section 3.4.2. Zhang et al. (2006a) found that 58% of the HVFDs could be classified as homonymous hemianopia (of which 13% had macular sparing), and 29% HVFDs were categorized as quadrantanopia. Homonymous scotomatous visual field defects formed 13% of the cases. Fujino et al. (1986) used a comparable classification. Homonymous hemianopia was present in 41% of the HVFD patients, and 37% of these had central field sparing. Quadrantanopia was present in 34% of the patients: 20% with a predominantly upper visual defect, and 14% with a predominantly lower visual defect. An irregular shape visual field defect, hemianopic scotoma, or bilateral visual field defects were present in 10%, 6%, and 9% of the cases, respectively. Zihl (2011) found 58% of the unilateral field defects to be a hemianopia, 17% a quadrantanopia, and 10% a paracentral scotoma. In a study of Trobe et al. (1973) 75% of the HVFD patients showed a unilateral homonymous hemianopia, 6% a bilateral homonymous hemianopia, 16% a homonymous quadrantanopia, and 3% a paracentral scotoma.

HVFD and its relation with health condition

The most common cause of HVFDs is damage to the occipital lobes (responsible for 45% of the HVFDs in Zhang et al. (2006a) and 51% in Fujino et al. (1986)). Another common etiology is damage to the optic radiations (32% in Zhang et al. (2006a) and 29% in Fujino et al. (1986)). Other, rarer causes are damage to the optic tract or to the lateral geniculate body.

HVFDs are most often caused by a stroke, but head trauma and brain tumors are also common (Fujino et al., 1986; Trobe et al., 1973; Zhang et al., 2006a; Zihl, 2011). According to the study of Zhang et al. (2006a), stroke was the main cause of HVFD, with cerebral infarction accounting for 59% and hemorrhage accounting for 11% of the HVFD cases. Other major causes were trauma (14%) and brain tumors (11%). In comparison, Trobe et al. (1973) found vascular occlusion to be the cause in 89% HVFDs patients--occlusion of the posterior cerebral artery in 86% and occlusion of the middle cerebral artery in 3% of the cases. Trauma was found to be the cause in 3.5%. Among the less common causes of HVFD are multiple sclerosis, seizure disorders, and the posterior form of Alzheimer disease (Trobe et al., 1973; Zhang et al., 2006a).

HVFD is one of the leading consequences of postchiasmatic brain damage; it has been estimated that 89% of patients with postchiasmatic brain injury have homonymous visual field defects (Zihl, 2011). To give an idea of the incidence in the total population, when visual fields were assessed in a large Australian urban elder community population (N = 3,216, age ≥ 49 years), HVFDs were present in 0.8% of the total sample and in 8.3% of those that had experienced a stroke (Gilhotra et al., 2002). Rossi et al. (1990) reported that 31% of the stroke patients in their inpatient rehabilitation unit had either homonymous hemianopia or visual neglect. Feigenson et al. (1977) found 31% of their stroke unit patients to suffer from

homonymous hemianopia. The difference in prevalence among these samples of stroke patients (8.3% vs 31%) could possibly be explained by a selection bias. Stroke patients without HVFD are less likely to be admitted to a stroke unit. The estimated percentage of patients suffering from hemianopia after stroke may also vary depending on the definition of hemianopia, time since stroke, and methodology used. The percentage of hemianopia was found to be 73% in a group of 2,738 patients with large infarction in the territory of the middle cerebral artery (Heinsius, Bogousslavsky, & Van Melle, 1998). In another study among a relatively small group of patients (*N* = 89) with posterior cerebral artery stroke, 54% had hemianopia (Ng, Stein, Salles, & Black-Schaffer, 2005). Van Stavern et al. (2001) found that of 326 patients with head trauma, 14% presented postchiasmatic visual field defects.

Activities and participation

Most patients with HVFD report reading problems and mobility problems (Gassel & Williams, 1963b; Trobe et al., 1973; Warren, 2009). Zihl (2011) mentions specific problems of bumping into obstacles and of wayfinding, especially in unfamiliar surroundings. According to Warren (2009), patients with HVFD face difficulties in daily life such as problems with driving, shopping (the result of orientation and mobility problems), meal preparation, financial management (the result of reading problems), personal hygiene or grooming, and watching television. Problems with regard to writing, reading, anxiety when walking in crowded surroundings, disorientation, and collisions with objects or people on the side of the visual field defect are self reported by 40-90%. Based on patients' self-assessments, both their vision-related and general quality of life are decreased by the visual field defect (Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010).

Environmental and personal factors

The performance of HVFD patients can be influenced by environmental and personal factors. A patient who lives next to a shopping center would have fewer problems with shopping than someone who lives in a rural area and is dependent on a driver's license or public transport. Examples of personal factors that could be of influence are age and gender. HVFDs have been observed at all ages, but they are most common in patients between ages 50 and 70 (Fujino et al., 1986; Trobe et al., 1973). Although some studies showed an equal occurrence of HVFDs among men and women (Zhang et al., 2006a), others found a higher occurrence in men (Fujino et al., 1986; Trobe et al., 1973). To our knowledge, no systematic studies have been performed on the frequency of other personal factors or environmental factors.

DATA EXTRACTION

The included publications (see Method of Literature Search) were classified into three categories: 1) studies describing the functioning of people with HVFD regardless of treatment, 2) studies about the effect of restorative training aimed at partial recovery of the lost visual field, 3) studies concerning the effect of compensatory training.

For each publication, each variable mentioned was allocated to one of the ICF components. Furthermore, each article was checked for predicting factors within the group of HVFD patients. A predictor was defined as a variable that was examined for its relationship with

Box 3.1. Categories of predicting factors.

Body Functions and Structures

- Visual functions, such as characteristics of the visual field, visual acuity, and contrast sensitivity
- Neuro-anatomical factors, such as lesion location, lesion size, and etiology
- Side of field defects. Because a distinction between left-sided and right-sided field defects is directly related to a distinction between left-sided and right-sided brain damage, this predicting factor could be ascribed to the visual functions as well as to the neuro-anatomical category. Therefore it was decided to create a separate category for comparisons between left-sided and right-sided field defects or brain lesions.
- Neuropsychological predictors, including neglect, awareness, and insight
- Other body functions and structures

Activities

- Activities, such as performance on reading tasks

Participation

- Participation, such as return to work, participation in social activities, etc.

Personal Factors

- Patient characteristics, such as age, gender, and time since lesion

Environmental Factors

- Environmental factors, such as contact with other patients in a vision rehabilitation clinic

Other

- Other variables. These are variables that do not fit in one of the other categories.

another variable. In case a correlation or association between two variables was described instead of a clear predictor-outcome combination, both variables were included as a predictor. This means that the predictors indicate statistical associations and not necessarily causal connections.

A number of predictor categories were distinguished, as presented in Box 3.1. The classification within the group of Body Functions and Structures was not based on the ICF, but was found helpful for structuring our findings.

The ICF is a helpful framework for categorizing the different variables examined by studies on HVFD. A large number of variables are explicitly listed in the ICF, such as visual field or visual acuity. In case a parameter was not explicitly listed, the authors made a collective decision, which was always unanimous. The categorization of some variables is explained here to prevent confusion. Because the ICF explicitly states that Body Functions also include mental functions, tests aimed at measuring neuropsychological constructs, such as the Trailmaking Test or the Line Bisection Test, were allocated to the Body Functions component. Eye movement parameters, such as fixation duration and saccade length during a visual search task, were also classified as Body Functions. The reaction time and accuracy of responses were categorized as measures of Activities, since these parameters are an indication of performance on a certain task, except for tasks that were clearly applied to measure an underlying body function, such as neuropsychological or perimetric tests.

The ICF lists a number of domains that could be applied for both Activities and Participation

and makes four suggestions with regard to the distinction between Activities and Participation. Here, the suggestions are applied to allow all domains to be part of both the Activities and the Participation component and not to allocate certain domains to Activities and certain domains to Participation in advance. A certain action or performance was classified as an Activity, unless it clearly defined a person's Participation, such as return to work and performing certain hobbies. In line with this reasoning, it was decided that the possession of a valid driver's license and the ability to use public transport were categorized as Activities. Having a driver's license does not necessarily define Participation, because one might not actually drive; obtaining a valid driver's license is an Activity closely related to Participation, however, because not having a license clearly restricts the possibilities of transport.

RESULTS

In total, 221 journal articles were considered for data extraction (references 1-10, 12-38, 40, 42-55, 57-59, 61-134, 136-144, 146-155, 157-159, 161-201, 203-218, 220-228, and 230-233 in Appendix 3.1). The results are presented in Table 3.1. The level of functioning in people with HVFD regardless of any intervention was addressed in 180 publications. In 31 publications the effect of restorative training was described, and the effect of compensatory training was discussed in 29 articles. Because an individual publication can address both the general functioning and the effect of training, the numbers in total exceed the total number of studies included (N = 221).

Besides knowing what factors have been found to predict another variable, called the outcome variable, it is also interesting to know the kind of outcome variables for which predicting factors have been examined. Therefore, every predictor-outcome connection was identified and it was decided to which ICF component each outcome variable belonged. Table 3.2 shows the number of predictor-outcome combinations that were found in terms of the ICF.

Table 3.1. Overview of variables described in 221 publications on HVFD, classified according to ICF.

Subject of publication	Variable	ICF level	No. of publications	References (Appendix 3.1)
Functioning without intervention *n* = 180	All variables	Body Functions and Structures	180 (100%)	
		Activities	50 (28%)	
		Participation	16 (9%)	
	Predictors	Body Functions and Structures		
		Visual functions (visual field characteristics, macula sparing, contrast sensitivity, visual acuity, eye movements, eccentric fixation, oculomotor functioning, color vision, hallucinations, visual phenomena)	73 (41%)	3, 4, 9, 18, 24, 29, 37, 38, 43, 44, 45, 46, 47, 48, 49, 53, 54, 55, 58, 64, 70, 79, 81, 82, 85, 95, 99, 101, 105, 109, 117, 119, 120, 134, 136, 140, 141, 144, 148, 149, 150, 154, 155, 157, 163, 172, 177, 180, 183, 187, 189, 192, 195, 196, 197, 198, 203, 204, 205, 206, 215, 217, 218, 222, 223, 224, 225, 226, 227, 231, 228, 232, 233
		Side of field defect	58 (32%)	2, 3, 13, 14, 20, 21, 22, 23, 32, 33, 34, 37, 42, 44, 47, 49, 58, 63, 69, 89, 91, 94, 98, 99, 106, 107, 109, 120, 121, 131, 139, 140, 144, 149, 154, 157, 163, 173, 179, 181, 187, 189, 190, 191, 192, 195, 196, 203, 205, 209, 217, 218, 226, 227, 228, 230, 231, 232
		Neuro-anatomy (lesion location, etiology, lesion size, degree of hypodensity of lesion, angiography, visually evoked potentials, cerebral dominance)	55 (31%)	4, 16, 18, 24, 29, 36, 38, 40, 43, 44, 46, 48, 49, 54, 55, 58, 59, 64, 70, 81, 82, 85, 94, 95, 105, 108, 111, 117, 119, 126, 134, 136, 139, 141, 148, 154, 183, 186, 189, 192, 195, 196, 198, 203, 204, 205, 209, 210, 215, 217, 223, 224, 225, 226, 231

Subject of publication	Variable	ICF level	No. of publications	References (Appendix 3.1)
		Neuropsychological predictors (awareness of deficits, insight, mental deterioration, level of consciousness, attention, depression, neglect, form perception, object recognition, visual processing speed, executive functioning, dyslexia, dysphasia, language deficits, apraxia)	24 (13%)	2, 3, 23, 37, 44, 45, 47, 48, 49, 69, 90, 94, 120, 122, 128, 171, 177, 187, 189, 203, 209, 215, 217, 231
		Other body functions and structures (arm position, head movements, paresis, hemiplegia, sensory disorder, tactile extinction, physical defects, physical complaints at onset)	9 (5%)	49, 58, 94, 182, 198, 203, 215, 218, 224
		Activities (reading performance, dot counting speed, search task performance, visuoperceptual behaviour during driving, driving performance)	12 (7%)	44, 47, 58, 140, 143, 149, 177, 217, 218, 227, 228, 231
		Participation	0 (0%)	
		Personal Factors (age, gender, time since lesion, driving experience, driving status, reading practice, age at onset of hemianopia, race)	43 (24%)	13, 14, 17, 21, 43, 44, 46, 48, 70, 78, 85, 97, 105,111, 120, 121, 126, 136, 139, 140, 149, 154, 163, 180, 181, 189, 191, 192, 195, 196, 198, 206, 209, 215, 217, 221, 224, 225, 226, 227, 230, 231, 232
		Environmental Factors	0 (0%)	
		Other (questionnaire scores: Visual Functioning Questionnaire, questionnaire of Kerkhoff, Cerebral Visual Disorders questionnaire, Driving Habits Questionnaire, Health Survey Short Form: SF-36; rate of illness onset)	10 (6%)	23, 45, 47, 58, 143, 154, 189, 203, 209, 228
		No predictors	59 (33%)	
Effect of restoration training *n* = 31	All variables	Body Functions and Structures	31 (100%)	
		Activities	11 (35%)	
		Participation	8 (26%)	
	Predictors	Body Functions and Structures		
		Visual functions (visual field characteristics, macula sparing, hallucinations)	9 (29%)	46, 78, 151, 152, 153, 154, 161, 162, 167
		Side of field defects	2 (6%)	75, 153
		Neuro-anatomy (etiology)	5 (16%)	26, 66, 78, 153, 176
		Neuropsychological predictors (attention level)	1 (3%)	153
		Other body functions and structures	0 (0%)	
		Activities	0 (0%)	

Subject of publication	Variable	ICF level	No. of publications	References (Appendix 3.1)
		Participation	0 (0%)	
		Personal Factors (age, gender, time since lesion)	9 (29%)	26, 66, 75, 78, 153, 154, 155, 162, 167
		Environmental Factors	0 (0%)	
		Other (subjective improvement in daily life)	2 (6%)	154, 167
		No predictors	17 (55%)	
Effect of compensatory training *n* = 29	All variables	Body Functions and Structures	29 (100%)	
		Activities	22 (76%)	
		Participation	3 (10%)	
	Predictors	Body Functions and Structures		
		Visual functions (visual field characteristics, eye movements, preferred illumination for reading, dark/light adaptation)	4 (14%)	89, 90, 230, 232
		Side of field defects	8 (28%)	91, 131, 144, 226, 227, 230, 231, 232
		Neuro-anatomy (lesion location, etiology)	3 (10%)	91, 227, 232
		Neuropsychological predictors (visual perception, visual object recognition, neglect)	2 (7%)	90, 164
		Other body functions and structures (head movements)	1 (3%)	90
		Activities (reading performance)	1 (3%)	89
		Participation	0 (0%)	
		Personal Factors (age, gender, time since lesion)	5 (17%)	90, 91, 138, 230, 232
		Environmental Factors (number of patients in clinic)	1 (3%)	12
		Other	0 (0%)	
		No predictors	16 (55%)	

Table 3.2. Number of predictor-outcome combinations classified according to the ICF.

Combination		General functioning	Restoration training	Compensatory Training
Predictor	Outcome			
Body	Body	248 (105)	18 (12)	20 (9)
Body	Act	104 (44)	5 (4)	12 (8)
Body	Part	21 (9)	2 (2)	-
Act	Body	12 (11)	-	1 (1)
Act	Act	9 (8)	-	1 (1)
Act	Part	5 (4)	-	-
Part	Body	-	-	-
Part	Act	-	-	-
Part	Part	-	-	-
Pers	Body	65 (37)	15 (9)	10 (4)
Pers	Act	33 (14)	1 (1)	6 (3)
Pers	Part	13 (6)	-	-
Env	Body	-	-	1 (1)
Env	Act	-	-	1 (1)
Env	Part	-	-	-
Other	Body	3 (3)	1 (1)	-
Other	Act	6 (6)	-	-
Other	Part	1 (1)	-	-

Body, Body Functions and Structures; Act, Activities; Part, Participation; Pers, Personal Factors; Env, Environmental Factors.

One publication could contain multiple combinations within the same category. For example, when an article mentioned the effect of both macula sparing and visual acuity on reading speed, it contributed two times to the Body-Act category. Therefore, the number of publications that mentioned one or more combinations of a certain category is depicted in parentheses.

ICF Components

With regard to the variables examined in the literature, it was found that all studies included variables at the level of Body Functions and Structures. This is not surprising since all studies examine HVFD, which by itself is a Body Function. Variables belonging to the Activities component were used more often in compensation studies (76%), as compared with studies on general functioning (28%) and restorative training (35%). Participation measures were more often described by restoration articles (26%), compared with compensation articles (10%) and articles on general functioning (9%).

With respect to the predicting factors it is interesting that all three types of studies (focusing on general functioning, restoration or compensation) mainly assessed the predicting effect of Body Functions and Personal Factors. Only one article examined the influence of Environmental Factors, and 33% of the publications on general functioning and 55% of restoration and compensation studies did not report on any predicting factors.

Most of the predictors were related to outcome variables belonging to the component Body Functions and Structures, the effect of predictors on certain Activities was studied less often. Although in studies on general functioning and restoration training a few predictors were related to Participation outcome, no predictors for Participation outcome were identified for compensatory training.

Predicting factors

The studies revealed several factors that were found to influence the level of functioning in patients with HVFD. Table 3.3 presents the evidence found for all the different predictors encountered.

Because it would take too much space to elaborate on each predictor, only the most relevant findings are described further. The selection of the predictors to be described here was based on relevance, frequency, and clarity in the original article. The predictors selected are assumed to be relevant for a wide range of researchers as well as professionals working in rehabilitation. In some articles, the predictors or their outcome parameters were not sufficiently explained or the descriptions of the predicting effects were ambiguous. In these cases, the predictors were not considered. For each predictor, the information is organized by outcome in such a way that first the outcome parameters on the Body Function level are discussed, followed by the Activities and Participation.

Predictors of functioning without intervention

Body functions and structures

Visual field characteristics – Some visual field characteristics were found to predict the spontaneous recovery of the HVFD. When the border between the intact and the affected region of the visual field was clearcut, less recovery could be expected than when a more gradual transition from the blind to the intact region was present (Zihl, Von Cramon, Brinkmann, & Backmund, 1977). A larger portion of incomplete VFDs recovered over time compared to the complete VFDs (C. S. Gray et al., 1989; Zhang et al., 2006b).

Size of the field defect was not related to search time on a visual search task, when search time was defined as the amount of deviation from the average search time of a healthy control group (Machner et al., 2009). Blythe et al. (1987) reported an absence of an association between size of HVFD and reading problems or bumping into obstacles on the blind side. The relationship between size of the HVFD and standardized quality of life measures has been examined in several studies, showing that a larger visual field defect may be related to an impaired quality of life according to some subscales, but not to others (Gall, Mueller, Kaufmann, Franke, & Sabel, 2008; Gall, Mueller, Gudlin et al., 2008; Gall, Lucklum, Sabel, & Franke, 2009; Gall, Franke et al., 2010; Gall, Wagenbreth, Sgorzaly, Franke, & Sabel, 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010). Several studies found that the extent of the visual field loss did not predict car-driving performance (Racette & Casson, 2005; Schulte, Strasburger, Muller-Oehring, Kasten, & Sabel, 1999; Wood et al., 2011), whereas other studies reported that patients with hemianopia were more impaired in car driving than patients with quadrantanopia (Elgin et al., 2010; Wood et al., 2009).

A number of studies found a predictive effect of macular sparing. HVFD patients with macular sparing were found to read faster (Lane et al., 2010; Papageorgiou et al., 2007; Trauzettel-Klosinski & Brendler, 1998; Zihl, 1995a) and to make less aberrant eye movements during reading (Leff et al., 2000; Trauzettel-Klosinski & Brendler, 1998; Zihl, 1995a). Machner et al. (2009), however, did not find a relation between macular sparing and search time on a visual search task. This inconsistent finding could be explained by the difference in task requirements. Information from the central visual field is highly important during reading,

Table 3.3. Evidence for predicting effects.

Predictor	General functioning	Restoration training	Compensatory training
Body Functions and Structures			
Visual functions			
Size, type and completeness of VFD	+	+	+
Maculasparing	+	±[1]	n/a
Congruency of VFD for both eyes	+	n/a	n/a
Visual acuity	+	n/a	n/a
Contrast sensitivity	+	n/a	n/a
Oculomotor functioning	±[1]	n/a	n/a
Eye movements	+	n/a	+
Eccentric fixation	±[1]	n/a	n/a
Preferred illumination for reading	n/a	n/a	-
Dark/light adaptation	n/a	n/a	-
Eye disease/deviation	+	n/a	n/a
Afferent pupillary defect	+	n/a	n/a
Visual phenomena/hallucinations	+	+	n/a
Side of field defect		±[2]	+
Neuro-anatomy			
Etiology	+	+	±[1]
Lesion location	+	n/a	±[1]
Lesion volume	-	n/a	n/a
Amount of damage in certain brain area/degree of hypodensity of lesion	±[1]	n/a	n/a
Cerebral dominance	-	n/a	n/a
Angiography	±[1]	n/a	n/a
EEG/VEP	±[1]	n/a	n/a
Hyperactivity as measured by MEG	±[1]	n/a	n/a
PET: I/C-ratio	±[1]	n/a	n/a
Neuropsychological predictors			
Global visuospatial tests/visual perception	+	n/a	-
Neglect	+	n/a	+
Form perception/ visual object recognition	-	n/a	-
Trailmaking Test part A	+	n/a	n/a
Trailmaking Test part B	+	n/a	n/a
Bells Test	+	n/a	n/a
Hidden Figures Test	+	n/a	n/a
Line bisection	+	n/a	n/a
Grey Scales	+	n/a	n/a
Executive functioning as measured with the DSST		n/a	n/a
Apraxia	-	n/a	n/a
Dyslexia	±[1]	n/a	n/a
Dysphasia	±[1]	n/a	n/a
Language deficits	-	n/a	n/a
Depression	+	n/a	n/a
Attention	±[1]	+	n/a
MMSE	-	n/a	n/a
Mental deterioration	-	n/a	n/a
Level of consciousness	±[1]	n/a	n/a
Hemianopic anosognosia/awareness of VFD/insight in VFD	+	n/a	n/a
Somatic anosognosia	+	n/a	n/a

Predictor	General functioning	Restoration training	Compensatory training
Other Body Functions and Structures			
Arm position	-	n/a	n/a
head movements	±[2]	n/a	+
hemiparesis/hemiplegia/hypotonia	+	n/a	n/a
Sensory disorder	+	n/a	n/a
tactile extinction	±[1]	n/a	n/a
Physical complaints at onset	-	n/a	n/a
Neurologic deficits	-	n/a	n/a
Activities			
Reading performance	+	n/a	+
Performance dot counting task	+	n/a	n/a
Performance search task	+	n/a	n/a
Visuoperceptual behaviour during driving (VIS)	-	n/a	n/a
Driving performance	+	n/a	n/a
Participation	n/a	n/a	n/a
Personal Factors			
Age	+	+	+
Gender	+	-	-
Time since lesion	+	±[1]	+
Driving experience	+	n/a	n/a
Driving status	+	n/a	n/a
Reading practice	±[1]	n/a	n/a
Age at onset of hemianopia	±[1]	n/a	n/a
Race	-	n/a	n/a
Environmental Factors			
Number of patients in clinic	n/a	n/a	+
Other			
Rate of illness onset	-	n/a	n/a
Subjective improvement in daily life	n/a	+	n/a
Visual Functioning Questionnaire	+	n/a	n/a
Health Survey Short Form: SF-36	+	n/a	n/a
Cerebral Visual Disorders	-	n/a	n/a
Kerkhoff-questionnaire	+	n/a	n/a
Driving Habits Questionnaire	±[2]	n/a	n/a

(+) a significant effect reported in at least one publication; (-) examined, but no evidence reported in any of the publications; (±[1]) at least one publication mentioned an effect, but without reporting the p-values; (±[2]) at least one publication reported that the data suggest an effect, but that this was not significant (often due to small sample sizes); (n/a) not examined in any of the publications.

whereas performance on visual search tasks depends more on peripheral information. Tant, Brouwer et al. (2002) did not expect macular sparing to influence on on-road driving performance; a significant positive correlation was found between the degrees of macular sparing and visual scanning behavior during driving, however. They suggested that macular sparing possibly leads to less difficulty with identifying objects, which makes it easier to compensate for the field defect. In a different on-road driving study (Elgin et al., 2010; Wood et al., 2009), 22 hemianopia patients were classified as either having macular sparing (*n* = 8) or not (*n* = 14). Here no significant difference between these two groups was found.

Side of field defect – The side of the field defect is one of the most examined predictors. In this context, it must be kept in mind that an effect of side of field defect might actually reflect

an underlying effect of which cerebral hemisphere is damaged. The term “left-sided HVFD patient” refers to a patient with right hemisphere damage leading to a visual field defect on the left side and vice versa.

Several visual search tasks have been used to assess visual scanning in hemianopia patients. Zihl (Zihl, 1995b; Zihl, 1999) asked HVFD patients how many dots were presented on a large screen, the right answer being 20. He found no difference between left-sided and right-sided HVFD patients with regard to the time necessary to count the dots. Side of field defect also had no influence on the eye movements during the task. Where Zihl only used one stimulus, Tant (2002) used 29 dot patterns, the number of dots ranging between 5 and 21 dots. He found that left-sided HVFD patients made more errors and showed, although not significantly, longer counting times compared with right-sided HVFD patients. Again, no influence of HVFD side on the eye movement parameters was found. Other studies found better visual search performance in left-sided HVFD patients compared with right-sided HVFD patients. When HVFD patients had to fixate in an ascending order numbers that were randomly distributed on a large screen, the right-sided HVFD patients had longer scanpaths, longer saccade durations, and longer reaction times. Several other scanning parameters, however, did not differ significantly between the two patient groups (Passamonti, Bertini, & Ladavas, 2009). When HVFD patients were asked to indicate whether or not one of 25 simultaneously presented squares was open at the top, the reaction was faster for left-sided than for right-sided HVFD patients, although this difference was not significant (Hildebrandt, Giesselmann, & Sachsenheimer, 1999). Machner et al. (2009) used a visual search paradigm in which participants had to detect 0, 1, 4, or 8 targets among a large number of distractors. Right-sided HVFD patients showed longer reaction times than left-sided HVFD patients, as well as a higher rate of refixations. No difference between left-sided and right-sided HVFD patients was found for the percentage of search time spent in the blind hemifield. Pambakian et al. (2000) asked HVFD patients to watch pictures, each presented for 3 seconds. Right-sided HVFD patients fixated more often on the picture area that corresponded to their blind hemifield than left-sided HVFD patients. This effect might be mediated by the awareness of the visual field loss. Because right-sided HVFD is caused by left hemisphere damage, these patients often have better awareness of their visual field loss than left-sided HVFD patients with right hemisphere damage and might therefore compensate better for their visual field defect by fixating more on the right side of the picture. No difference, however, was found for side of HVFD with regard to the total fixation time on the blind side of a picture. No difference was found for side of HVFD concerning the percentage of saccades towards the blind side. To summarize, there is some inconsistency in the results of studies that examined scanning efficiency with regard to the effect of side of HVFD, which could possibly be explained by the differences among tasks used in different studies.

HVFD patients often report difficulty with reading. Patients with a right-sided HVFD experience different problems with reading than left-sided HVFD patients. Patients with left-sided HVFD often reported problems with finding the beginning of a new line, whereas those with right-sided HVFD had more trouble with smoothly reading along the line (Kerkhoff, Munssinger, Eberlestrauss, & Stogerer, 1992; Schuett, Heywood, Kentridge, & Zihl, 2008). Objective measurements confirm that left-sided HVFD patients make more saccades during the

return sweep to the next line than right-sided HVFD patients (Passamonti et al., 2009; Trauzettel-Klosinski & Brendler, 1998). Right-sided HVFD patients showed a higher number of progressive saccades, as well as more regressions (Passamonti et al., 2009; Trauzettel-Klosinski & Brendler, 1998) and longer fixation durations (Zihl, 1995a), compared with left-sided HVFD patients. With regard to the speed of reading, right-sided HVFD patients were found to be more impaired than left-sided HVFD patients (Lane et al., 2010; Papageorgiou et al., 2007; Trauzettel-Klosinski & Brendler, 1998; Zihl, 1995a). HVFD in the right hemifield was also associated with more reading errors (Passamonti et al., 2009). These results were found for languages written from left to right. Different results might be found for other writing systems.

Several studies have assessed the effect of side of field defect on car-driving performance, either in a driving simulator (Bowers, Mandel, Goldstein, & Peli, 2010; Szlyk, Brigell, & Seiple, 1993) or on the road (Elgin et al., 2010; Racette & Casson, 2005; Tant, Brouwer et al., 2002; Wood et al., 2009; Wood et al., 2011). Although some studies found differences between left-sided and right-sided HVFD patients, others did not.

Etiology and lesion location - Zhang et al. (2006b) found that spontaneous recovery of the HVFD was not significantly associated with either etiology or lesion location. Tiel and Kölmel (1991), however, found a relation between lesion location and the location of visual field recovery. Dromerick and Reding (1995) examined hemianopia patients who also had hemiparesis and hemisensory loss. When patients with cortical, subcortical, or mixed lesion were compared, no difference was found for impairments in activities of daily life, self care, and ambulation at the time of admission in an inpatient stroke rehabilitation unit. A nonsignificant trend was found for cortical patients to have a shorter stay in the rehabilitation unit and to have a better self care and ambulation score on time at discharge. Miyai et al. (1997) examined a similar patient group and also found that patients with cortical lesions scored better on self care and ambulation on time of admission than patients with basal ganglia lesions. The patients with the cortical lesions had a shorter length of stay compared with the basal ganglia patients, although this difference was not significant. Lesion location did not influence whether patients went home after discharge or to a nursing home. Damage to the occipitotemporal (fusiform) gyrus, the parahippocampal gyrus, and parts of the inferior occipital lobe was found to be related to a poorer performance on visual scanning tasks (Hardiess, Papageorgiou, Schiefer, & Mallot, 2010). No predictive value of etiology was found for the majority of subscales of quality of life questionnaires (Gall, Mueller, Gudlin et al., 2008; Gall et al., 2009; Gall, Franke et al., 2010) as well as for visual scanning behavior during driving (Tant, Brouwer et al., 2002) or safety of driving (Wood et al., 2009).

Neuropsychological predictors – In 1962 Warrington (1962) reported on the importance of awareness of the visual field defect. She found that awareness was strongly associated with "imaginative completion". Hemianopia patients who were not aware of their visual field defect reported that they saw a complete figure when presented with an incomplete figure with the missing part being located in the hemianopic field. Hemianopia patients who were aware of their visual field defect did not show this phenomenon of completion. Related to this, completion was also associated with neglect, but not with mental deterioration. Gassel and Williams (1963b) reported that insight in the visual field defect was not only related to the phenomenon of completion, but also to visual functioning in daily life activities, as assessed by

interviews with patients and close relatives. Several studies reported that HVFD patients with additional neglect were found to be more impaired than HVFD patients without neglect on all kind of tasks, such as visual search tasks (Meienberg, 1983; Meienberg, Harrer, & Wehren, 1986; Muller-Oehring et al., 2003) and scanning during driving in a driving simulator (Szlyk et al., 1993).

The predicting value of neuropsychological tests on driving performance has been examined by several studies (Elgin et al., 2010; Szlyk et al., 1993; Tant, Brouwer et al., 2002; Wood et al., 2009). Wood et al. (2009) found performance on the Trailmaking Test part A to be lower in the patients who had stopped driving compared with the patients who continued driving. No relation was found between current driving status and scores on the Mini-Mental Status Examination, the Digit Symbol Substitution Test, or the Trailmaking Test part B. The safety of on-road driving was predicted by the performance on the Trailmaking Test part A and the Digit Symbol Substitution Test, but not by the Mini-Mental Status Examination and the Trailmaking Test part B. Elgin et al. (2010) confirmed that safety of driving was related to performance on the Trailmaking Test part A. Tant, Brouwer et al. (2002) found that visual performance during driving could be predicted by the scores of HVFD patients on the Grey Scales, the Bells Test, the Trailmaking Test part B, and the Hidden Figures Test.

Personal Factors

Personal factors – Several studies provide evidence that time since lesion influenced visual scanning parameters. When HVFD patients were asked to look back and forward between the examiner's two fingers, the saccade towards the finger in the blind hemifield was shorter for patients with a time since lesion shorter than six months than those with HVFD for a longer time period (Meienberg, 1983). Zihl (1995b) found that patients with a shorter time period since lesion showed a longer search time and less efficient scanning when 20 dots had to be counted. When participants were asked to view pictures (Pambakian et al., 2000), HVFD patients with longer time periods since lesion showed fixation patterns that deviated more from the fixation patterns of healthy controls compared with patients with shorter time periods since lesion. These results indicate that HVFD patients might learn to compensate for their HVFD spontaneously over time, although Meienberg (1988) did not find an association between time since lesion and visual scanning. Although some studies did not find a significant effect of time since lesion on reading speed, reading errors (Zihl, Krischer, & Meissen, 1984), and eye movements during reading (Zihl, 1995a), Trauzettel-Klosinski and Brendler did (1998). For right-sided HVFD patients they found that an increased time since lesion was related to a higher reading speed as well as fewer saccades and regressions per line. For left-sided HVFD patients the number of saccades during the return sweep to the next line decreased over time. Time since lesion did not influence driving performance (Bowers, Mandel, Goldstein, & Peli, 2009; Schulte et al., 1999; Wood et al., 2009), although Tant et al. found a relation between time since lesion and scanning behavior during driving (Tant, Brouwer et al., 2002). No influence of time since lesion on quality of life has been reported, except for the subscales measuring role difficulties (Gall et al., 2009; Gall, Franke et al., 2010; Papageorgiou et al., 2007).

Age was not found to influence the spontaneous recovery of the visual field (Tiel & Kolmel,

1991; Zhang et al., 2006b). Reading speed was found to be related to age, showing that younger HVFD patients read faster than older HVFD patients (Trauzettel-Klosinski & Brendler, 1998). This effect, however, was not as pronounced as in healthy controls. Other studies did not find an association between age and reading speed, reading errors (Zihl et al., 1984), and eye movements during reading (Zihl, 1995a). Although it was found that older HVFD patients showed more impairment in visual behavior during driving (Bowers et al., 2009; Tant, Brouwer et al., 2002), Wood et al. reported that age was not related to safety of driving (Wood et al., 2009). Additionally, where some studies found that older HVFD patients displayed a poorer quality of life (Gall, Mueller, Gudlin et al., 2008; Gall et al., 2009), others found no association (Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010).

Several studies examined the influence of gender. Spontaneous recovery of the HVFD was not predicted by gender (Tiel & Kolmel, 1991; Zhang et al., 2006b). Eye movements during reading were also not found to be different for men and women (Zihl, 1995a). Furthermore, gender did not predict scanning behavior during driving (Tant, Brouwer et al., 2002). Although several studies found no significant differences for men and women on quality of life (Gall, Mueller, Gudlin et al., 2008; Papageorgiou et al., 2007; Wagenbreth et al., 2010), Gall et al. found an effect of gender on the subscale physical functioning as well as on the physical and mental composite scores (Gall, Franke et al., 2010).

Predictors of the effect of restorative training

There is still considerable controversy whether restorative training truly expands the visual field or whether unsteady fixation during perimetry assessment confounded the results. When Reinhard et al. (2005) controlled fixation stability during perimetry by assessing scanning laser ophthalmoscope fundus monitoring, no improvement of the absolute border of the visual field was found following restorative training.

Body functions and structures

Visual field characteristics - A number of studies related characteristics of the visual field to the effect of restorative training. Poggel et al. (Poggel, Mueller, Kasten, & Sabel, 2008) found that the size of the field defect within the central 30^{o} was related to the visual field gain after restorative training; a larger intact central visual field corresponded to more visual field gain. This is in accordance with the finding of Kasten and Sabel (1995) showing that smaller field defects were related to a larger increase of the visual field. In a study of Sabel et al. (2004), visual field gain by restorative therapy was statistically comparable for patients with complete hemianopia and patients with incomplete hemianopia, quadranopia, or paracentral scotomas, but the effect size was again slightly larger in the latter group. A variable related to the visual field size is the size of the area of residual vision (ARV), which is the area of the visual field that is not completely blind, but has a higher light detection threshold than the intact visual field. A larger ARV before training resulted in more visual field gain (Poggel, Kasten, & Sabel, 2004; Poggel, Mueller, Kasten, Bunzenthal, & Sabel, 2010) and an improvement in color and form perception (Poggel, Mueller et al., 2008) following restorative training. Related to this is the finding that restorative training was less likely to increase the visual fields of patients with a steep border between the intact and affected visual field (Poggel et al., 2010). The influence of

visual field size was also found to extend to vision-related difficulties in daily life. Patients with complete hemianopia showed less improvement on a standardized vision-related quality of life questionnaire compared to patients with smaller field defects (Gall, Mueller, Gudlin et al., 2008). The amount of increase in visual field size after restorative training was positively and significantly related to the visual related activities and quality of life (Gall, Mueller, Gudlin et al., 2008; Poggel et al., 2010).

Etiology - No clear conclusion could be drawn about the influence of etiology on the amount of visual field increase after restorative training. One study (Schmielau & Wong, 2007) showed that patients who experienced a hemorrhage benefitted more than patients who experienced an infarction when kinetic perimetry was used, but this effect disappeared when the visual field was measured by static perimetry. Poggel, Mueller et al. (2008) found no differences in training effect for patients who suffered from stroke and patients who suffered from vascular malformations or aneurysm surgery.

Personal factors

Personal factors - Besides the predictors related to visual field characteristics and etiology, a number of personal factors were found to influence the effect of restorative training. Although some studies revealed that age was not significantly related to visual field gain (Kasten, Bunzenthal, & Sabel, 2006; Romano, Schulz, Kenkel, & Todd, 2008; Sabel et al., 2004) or to an improvement of visual motion perception (Huxlin et al., 2009), Poggel, Mueller et al. (2008) found that older patients improved significantly more with regard to visual field size, form recognition, and color discrimination compared with younger patients. Time since lesion was not found to influence the effect of restorative training on visual field gain (Huxlin et al., 2009; Kasten & Sabel, 1995; Poggel, Mueller-Oehring, Kasten, Bunzenthal, & Sabel, 2008; Poggel, Mueller et al., 2008; Romano et al., 2008; Sabel et al., 2004) or on the improvement in color and form perception (Poggel, Mueller et al., 2008). These studies almost exclusively examined patients in the chronic phase with a considerable variation in time since lesion. One study examining the effect of gender on visual and attentional effects of restorative training found no significant difference (Poggel, Mueller et al., 2008).

Predictors of the effect of compensatory training

Body functions and structures

Visual field characteristics - The literature is ambiguous about the influence of visual field characteristics on the effect of compensatory training. In one study (Kerkhoff, Munssinger, Haaf et al., 1992) 122 patients with HFVD followed a systematic scanning training. This compensatory training enlarged the visual field in part of the group, but the increase in visual field was not related to the increase in visual search field, defined as the area in which eye movements were made when searching for a bright light. The size of the visual search field before training was negatively related to the amount of visual search field gain; patients with smaller initial visual search fields had a larger increase in visual search field. The preferred illumination for reading, dark/light adaptation, and visual object recognition did not explain the visual search field gain. Zihl and von Cramon (1985) found that eccentricity of the visual field border, a variable related to the size of the field defect, did not influence the amount of

saccadic training necessary to increase the visual field. The subjective improvement of visual field did depend on the eccentricity of the visual field border. Patients with a field defect near the macula needed less visual field gain to subjectively notice an improvement in their visual field, compared with patients in which the initial visual field border was more than 10^{o} away from the center. Furthermore, this study showed that an increase in visual field caused an improvement in reading performance.

Side of field defect – Another factor analyzed for its influence on the effect of compensatory training was side of the HVFD. Kerkhoff et al. (1994) found no difference between left-sided and right-sided HVFD with regard to the visual field gain or the visual search field gain after compensatory scanning training. Other studies also found no influence of side of lesion on visual field gain by scanning-specific and reading-specific oculomotor training (Zihl et al., 1984; Zihl & Von Cramon, 1985; Zihl, Saemann, Schenk, Schuett, & Dauner, 2009). The side of the field defect was found to have an effect on reading performance. Zihl (1995a) examined the effect of a reading training, in which patients were instructed to make certain eye movements during reading. Patients with right-sided visual field loss needed more training sessions than left-sided HVFD patients to reach the same reading scores as healthy participants. In a study by Passamonti, Bertini and Lavadas (2009) the effect of an audiovisual scanning training was analyzed. For patients with right-sided HVFD, there was an improvement in reading performance, a decrease of progressive and regression saccades, a decrease in fixation duration, and an increase of saccadic amplitude. Patients with left-sided HVFD on the other hand, only benefitted from the training by a decrease in the number of saccades when searching for the beginning of the next line. The eye movement parameters on a visual search task in left-sided HVFD patients became similar to those of healthy controls in the follow-up period, while the right-sided HVFD patients still showed aberrant visual scanning.

Etiology and lesion location - Several studies found no influence of the cause of brain damage on visual field gain (Zihl & Von Cramon, 1985), visual search field gain (Kerkhoff, Munssinger, Haaf et al., 1992) or the improvement in visual search tasks after compensatory scanning training (Kerkhoff et al., 1994). In the area of regained visual field, color and form recognition recovered in most of the patients with posterior cerebral infarction, whereas in most with closed head trauma, only light detection came back after scanning training (Zihl & Von Cramon, 1985). With regard to the predicting effect of lesion location, it was found that damage to both the posterior thalamus and the occipitoparietal cortex has a negative influence on the effect of scanning training (Zihl, 1995b). On the other hand, Kerkhoff et al. (1994) found no influence of lesion location on visual field gain, visual search field gain, or performance on visual search tasks.

Head movements - The use of head movements during scanning training is found to influence the effect of compensatory training. Patients who made more and larger head movements needed significantly more training sessions to obtain the same amount of visual search field gain (Kerkhoff, Munssinger, Haaf et al., 1992).

Neglect - Although neglect did not influence visual field gain after compensatory scanning training (Kerkhoff, Munssinger, Haaf et al., 1992), patients with HVFD accompanied by neglect needed 25% more training sessions to regain the same amount of visual search field as patients without neglect.

Personal factors

Personal factors – Some studies analyzed the predicting effect of age, time since lesion, or gender. No predicting influence of age has been found on visual field gain (Zihl et al., 1984; Zihl & Von Cramon, 1985), visual search field gain (Kerkhoff, Munssinger, Haaf et al., 1992), improvement on visual tests (Kerkhoff et al., 1994) or improvement in reading performance (Zihl et al., 1984) by compensatory training. Pambakian et al. (2004) however, found that older patients improved more on activities on daily life after visual search training. Time since lesion also did not influence visual field gain (Zihl et al., 1984; Zihl & Von Cramon, 1985), visual search field gain (Kerkhoff, Munssinger, Haaf et al., 1992) and visual performance improvement (Kerkhoff et al., 1994). On the other hand, Zihl et al. (1984) found that the longer the time since lesion, the more reading training sessions were necessary. According to Kerkhoff et al. (1994) men and women did not differ on their improvement of visual performance by scanning training. Zihl and von Cramon (1985) also found no gender differences for visual field gain.

Environmental factors

Prism glasses have been used for patients with HVFD (Bowers, Keeney, & Peli, 2008; Giorgi, Woods, & Peli, 2009; Peli, 2000; Rossi et al., 1990; Szlyk, Seiple, Stelmack, & McMahon, 2005). Patients were more inclined to keep using the glasses in the clinics where eight or more HVFD patients received prism glasses, compared with clinics with a maximum of five patients (Bowers et al., 2008). No explanation has been found for this finding. It is worth mentioning that the total number of HVFD patients in the clinics is the only predicting factor within the Environmental Factors component encountered in the current review.

DISCUSSION

Options for rehabilitation programs are increasing for patients with HVFD. These programs aim for improvement at different levels of functioning. To estimate whether or not a certain intervention will help the patient, it is necessary to make a prediction about the future functioning of this patient and about the effect of specific training. Therefore, we have tried to increase awareness of the focus of previous research on HVFD patients and to give an overview of the variables that are already known to predict HVFD patients' level of functioning or the effect of treatment.

Some shortcomings have to be mentioned. The ICF was chosen as a framework for classifying the literature. Although the ICF is of great help in distinguishing different levels of functioning, it has limitations, as already mentioned in the Method section. The ICF therefore forms a valuable starting point, but has to be extended with specific parameters when being applied within the context of a specific research area.

We did not take into account the quality of the studies. This means that Table 3.3 is the result of an exploration of the influence of the different predictors, neglecting the fact that sample size and research methods obviously influence the results. Because thoroughly analyzing the size and strength of the predicted effects would require examination of the sample sizes, specific patient characteristics, and research methods of all 221 articles, this fell beyond the scope of this review. The aim of future studies could be to examine the relationships between a selection of interesting parameters in more detail by further analyzing

the research methods and effects found. A final remark on Table 3.3 is that predictors for which no effect has been found might be underrepresented as a result of a bias making publication of nonsignificant research findings less likely.

Despite these shortcomings, however, we found several interesting results. As explained in the Method section, all tasks, except for tasks measuring an underlying body function, were allocated to the component Activities. This resulted in a very broad range of Activities (i.e., from the time necessary to count a number of dots to the performance on a driving test). Although every study under investigation included variables at the level of Body Functions and Structures, fewer studies considered Activities, however, and even fewer took measures of Participation into account. The finding that compensation studies were, compared with restoration studies, more focused on activities could possibly be explained by the nature of the training. Restorative training aims at improving the visual field itself, which is clearly a Body Function, whereas compensation often aims at improving performance on search tasks or to improve mobility activities. The finding that restoration studies more often reported on participation outcome compared to compensation studies is more difficult to explain. In this context, it is important to consider that the investigation of participation outcome in most of the studies examining the effect of restoration or compensation was not very elaborate. Articles were frequently allocated to the Participation category because only one question related to whether patients returned to work or pursued their hobbies.

Although the original ICF framework includes causal arrows between all the different components, in the case of HVFDs not all these relations are equally relevant. Important issues in rehabilitation are, for example, the influence of visual field size (Body Function) on the degree of reading problems (Activity) or the influence of avoiding obstacles (Activity) on the ability to go shopping independently (Participation). Although an improvement in participation could lead to improvements in certain activities by means of a learning effect, the focus of research as well as clinical work is usually on causalities in the other direction. Therefore, it is not surprising that most predictors were found to be of the component Body Functions and Structures and that no predictors were found in the Participation component. More surprising is the finding that little attention has been paid to the relationship between Activities and Participation measures. None of the studies on compensatory training, and relatively few studies on general functioning or restorative training, examined the effect of some predictor on participation. Besides the causalities between Body Functions and Activities and between Activities and Participation, the influence of Personal and Environmental Factors on functioning is also relevant. Personal factors are among the most examined predictors, and only one study included an environmental factor as a possible predictor. In daily life, environmental factors greatly influence the activities one performs and participation in society. At this time, the literature on HVFD gives us no information about environmental factors.

We have three recommendations for future studies. First, to allow comparison across studies and the possibility of meta-analyses, researchers should be aware of and report on the ICF components and domains they are focusing on. In this context, it is also noteworthy that restorative and compensatory training are aiming at improvement of different ICF domains, which should be taken into account when discussing the use of both training approaches. Although restorative training primarily focuses on improving the visual field (ICF code b2101),

compensatory training teaches the patient to apply scanning strategies in daily life – for example, to improve mobility (ICF code d4). Only if compensation and restoration studies use the same outcome measures is a comparison between the two approaches possible. The study of Roth et al. represents a good example of such a comparison (Roth et al., 2009). A second recommendation with regard to the ICF is to use measurements of Participation more frequently. From a rehabilitation perspective, the most important outcome of an intervention is whether it benefits patients in their daily life. Because participation depends heavily on the capacity for certain activities and on the functioning of certain body parts, it is important to know through which body functions and activities a training could improve participation. Possibly, new measures for participation are necessary to gain more insight into these relationships, although measuring participation is complicated due to standardization problems. Third, more knowledge is necessary with regard to the influence of certain predictors on the level of functioning of patients with HVFDs.

CONCLUSION

Analyzing 221 publications on HVFD showed that studies in this field focus most on Body Functions, less on Activities, and almost never on Participation. Because an important goal of rehabilitation is to improve a patient's participation, future studies on intervention effects should include participation outcome measures. The existing literature on interventions for HVFD is of little help when one must decide whether and which training to give to individual patients. Additional research is necessary to identify those factors that predict both the level of functioning of patients with HVFDs and the effects of training. The ICF helps to clarify the scope of the existing literature, and it is recommended to consider this framework when designing future studies.

METHOD OF LITERATURE SEARCH

The literature search was performed in June 2011. The Web of Science database (including the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index databases) was searched for journal publications on HVFDs by using the search strategy as presented in Box 3.2.

Based on the abstracts, those studies were included that described a clearly specified number of adults with field defects described as homonymous hemianopia or homonymous visual field defects mainly restricted to one half of the visual field. Only English and German publications were included, which resulted in exclusion of a number of articles in French. Supplements, meeting abstracts, notes, and letters to editors were not included.

The included publications were then assessed on their content. The literature search was restricted to human adults. A number of studies on children, monkeys, and cats with HVFD, or simulated HVFD in healthy people, were therefore excluded. Articles about transient field defects in cases of epilepsy, migraine, or hyperglycemia were not included. Case studies (n = 1) were also excluded.

Besides studies on the subject of HVFD, reviews were also included for further analysis. For the reviews, the same inclusion criteria were applied as for the studies. The reviews were

Box 3.2. Search strategies in web of science.

1	Hemianopia (title)
2	Hemianopia (topic, not title) AND predict* (title or topic) / training (title or topic) / therapy (topic) / participation (topic) / participate (topic) / quality of life (topic) / daily (topic) / compensation (topic) / correlates (topic) / prognostic (topic) / prognosis (topic) / demographic (topic) / neuropsycholog* (topic) / cognitive (topic)
3	Hemianopic (title) AND NOT hemianopia (title)
4	Hemianopic (topic, not title) AND NOT hemianopia (title or topic) AND NOT hemianopsia (title or topic)
5	Visual field defect (title) AND predictors (title)
6	Visual field defect (topic) AND predictors (topic)
7	Visual field defect (topic) AND predicting (topic)
8	Cerebral blindness (topic) AND NOT hemianopia (topic) AND predictors (topic) / predicting (topic) / training (topic) / therapy (topic) / participat* (topic) / quality (topic) / daily (topic) / compensation (topic) / correlates (topic) / prognos* (topic) / demographic (topic) / neuropsychologic* (topic) / cognitive (topic)
9	Cortical blindness (topic) and not hemianopia (topic) AND predict* (topic) / training (topic) / therapy (topic) / participat* (topic) / quality of life (topic) / daily (topic) / compensation (topic) / correlates (topic) / prognos* (topic) / demographic (topic) / neuropsychologic* (topic) / cognitive (topic)
10	Hemianopsia (title) AND NOT hemianopia (title or topic)
11	Hemianopsia (topic, not title) AND NOT hemianopia (topic) AND predict* (topic) / correlates (topic) / prognosis* (topic) / demographic (topic) / training (topic) / compensation (topic)
12	Homonymous and Field and Defects (title) AND NOT Hemianopic (title) AND NOT hemianopia (topic or title) AND NOT hemianopsia (topic or title)
13	Homonymous and Field and Defects (topic, not title) AND NOT Hemianopic (title) AND NOT hemianopia (title or topic) AND NOT hemianopsia (title or topic)

checked for statements about predicting factors and corresponding references were added to the data file in case they were not yet included.

SUPPLEMENTARY MATERIAL

Supplementary material related to this article can be found at http://dx.doi.org/10.1016/j.survophthal.2013.02.006.

APPENDIX 3.1: REFERENCE TABLE

1	(Alexander & Cowey, 2009)
2	(Barton, Behrmann, & Black, 1998)
3	(Barton & Black, 1998)
4	(Barton & Sharpe, 1997)
5	(Beal & Chapman, 1980)
6	(Bergsma & Van der Wildt, 2010)
7	(Bergsma & Van der Wildt, 2008)
8	(Biersdorf, Bell, & Beck, 1992)
9	(Blythe et al., 1987)
10	(Bolognini, Rasi, Coccia, & Ladavas, 2005)
12	(Bowers et al., 2008)
13	(Bowers et al., 2009)
14	(Bowers et al., 2010)
15	(Brandt, Bucher, Seelos, & Dieterich, 1998)
16	(Braun, Weber, Schiefer, Skalej, & Dietrich, 2001)
17	(Bridge, Jindahra, Barbur, & Plant, 2011)
18	(Brigell, Celesia, Salvi, & Clarkbash, 1990)
19	(Bruce, Zhang, Kedar, Newman, & Biousse, 2006)
20	(Butter, Kosslyn, MijovicPrelec, & Riffle, 1997)
21	(Bynke, 1984)
22	(Cavezian et al., 2010)
23	(Celesia, Brigell, & Vaphiades, 1997)
24	(Celesia, Meredith, & Pluff, 1983)
25	(Chen et al., 2009)
26	(Chokron et al., 2008)
27	(Cohn, 1972)
28	(Corin & Bender, 1972)
29	(Crevits & Vanlith, 1983)
30	(Danckert et al., 2003)
31	(Dekeyser, Neetens, & Vissenberg, 1991)
32	(Doehring & Reitan, 1961a)
33	(Doehring & Reitan, 1961b)
34	(Doehring, Reitan, & Klove, 1961)
35	(Doricchi, Onida, & Guariglia, 2002)
36	(Dromerick & Reding, 1995)
37	(Elgin et al., 2010)
38	(Engler, Zihl, & Poppel, 1993)
40	(Ferber & Karnath, 2001)
42	(Fujino et al., 1986)
43	(Gall, Franke et al., 2010)
44	(Gall et al., 2009)
45	(Gall, Mueller, Kaufmann et al., 2008)
46	(Gall, Mueller, Gudlin et al., 2008)
47	(Gall, Wagenbreth et al., 2010)
48	(Gassel & Williams, 1963b)
49	(Gassel & Williams, 1963a)
50	(Gedik, Akman, & Akova, 2007)
51	(Gilhotra et al., 2002)
52	(Giorgi et al., 2009)
53	(C. S. Gray et al., 1989)
54	(L. G. Gray, Galetta, & Schatz, 1998)
55	(L. G. Gray, Galetta, Siegal, & Schatz, 1997)
57	(S. W. Han, Sohn, Lee, Suh, & Choi, 2000)
58	(Hardiess et al., 2010)
59	(Harrington, 1961)

61 (Hellner, Jensen, & Mullerjensen, 1978)
62 (Hess & Pointer, 1989)
63 (Hildebrandt et al., 1999)
64 (Horton & Hoyt, 1991)
65 (Huber, 1962)
66 (Huxlin et al., 2009)
67 (Hyvarinen, Raninen, & Nasanen, 2002)
68 (Isa, Miyashita, Yanagimoto, Nagatsuka, & Naritomi, 2001)
69 (Ishiai, Furukawa, & Tsukagoshi, 1987)
70 (Jacobson, 1997)
71 (Jahnke, Denzler, Liebelt, Reichert, & Mauritz, 1995)
72 (Jamara, Van de velde, & Peli, 2003)
73 (Jobke, Kasten, & Sabel, 2009)
74 (Julkunen, Tenovuo, Jaaskelainen, & Hamalainen, 2003)
75 (Kasten et al., 2006)
76 (Kasten, Muller-Oehring, & Sabel, 2001)
77 (Kasten, Poggel, & Sabel, 2000)
78 (Kasten & Sabel, 1995)
79 (Kasten, Wuest, & Sabel, 1998)
80 (Kasten, Wust, Behrens-Baumann, & Sabel, 1998)
81 (Kattah, Dennis, Kolsky, Schellinger, & Cohan, 1981)
82 (Kaul, Boulay, Kendall, & Russell, 1974)
83 (Kearns & Rucker, 1959)
84 (Kedar, Zhang, Lynn, Newman, & Biousse, 2006)
85 (Kedar, Zhang, Lynn, Newman, & Biousse, 2007)
86 (H. M. Keller, Meyer, Valavanis, & Imhof, 1988)
87 (I. Keller & Lefin-Rank, 2010)
88 (Kerkhoff, Artinger, & Ziegler, 1999)
89 (Kerkhoff, Munssinger, Eberlestrauss et al., 1992)
90 (Kerkhoff, Munssinger, Haaf et al., 1992)
91 (Kerkhoff et al., 1994)
92 (Kiyosawa et al., 1990)
93 (Knox & Cogan, 1962)
94 (Koehler, Endtz, Velde, & Hekster, 1986)
95 (Kollias et al., 1998)
96 (Kolmel, 1984)
97 (Kolmel, 1985)
98 (Landis & Regard, 1988)
99 (Lane et al., 2010)
100 (Leff et al., 2001)
101 (Leff et al., 2000)
102 (Leh, Mullen, & Ptito, 2006)
103 (Leo, Bolognini, Passamonti, Stein, & Ladavas, 2008)
104 (Lepore, 2001)
105 (Lesevre, 1982)
106 (Lewald, Peters, Tegenthoff, & Hausmann, 2009a)
107 (Lewald, Peters, Tegenthoff, & Hausmann, 2009b)
108 (Maccolini, Andreoli, Valde, Ghini, & Fulco, 1986)
109 (Machner et al., 2009)
110 (Mannan, Pambakian, & Kennard, 2010)
111 (Manor, 1989)
112 (Marshall, Chmayssani, O'Brien, Handy, & Greenstein, 2010)
113 (Marshall et al., 2008)
114 (Martin, Riley, Kelly, Hayhoe, & Huxlin, 2007)
115 (Mattingley et al., 2004)
116 (Matwijecky & Steinbok, 1982)

117	(Mcauley & Russell, 1979)
118	(McDonald, Spitsyna, Shillcock, Wise, & Leff, 2006)
119	(Meienberg, 1981)
120	(Meienberg, 1983)
121	(Meienberg, 1988)
122	(Meienberg et al., 1986)
123	(Meienberg, Zangemeister, Rosenberg, Hoyt, & Stark, 1981)
124	(Miki et al., 2005)
125	(Miki, Nakajima, Fujita, Takagi, & Abe, 1996)
126	(Miyai et al., 1997)
127	(Mueller, Gall, Kasten, & Sabel, 2008)
128	(Muller-Oehring et al., 2003)
129	(Nelles, De Greiff, Pscherer, Forsting et al., 2007)
130	(Nelles, De Greiff, Pscherer, Stude et al., 2007)
131	(Nelles et al., 2001)
132	(Nelles et al., 2009)
133	(Nelles et al., 2010)
134	(Newman & Miller, 1983)
136	(Ostertag & Unsold, 1981)
137	(Pai, 1997)
138	(Pambakian et al., 2004)
139	(Pambakian et al., 2000)
140	(Papageorgiou et al., 2007)
141	(Papageorgiou et al., 2008)
142	(Paramei & Sabel, 2008)
143	(Parker et al., 2011)
144	(Passamonti et al., 2009)
146	(Peli, 2000)
147	(Perenin, 1991)
148	(Pessin et al., 1987)
149	(Pflugshaupt et al., 2009)
150	(Poggel, Kasten, Mueller-Oehring, Bunzenthal, & Sabel, 2006)
151	(Poggel et al., 2004)
152	(Poggel et al., 2010)
153	(Poggel, Mueller et al., 2008)
154	(Poggel et al., 2007)
155	(Poggel, Mueller-Oehring et al., 2008)
157	(Racette & Casson, 2005)
158	(Rafal, Smith, Krantz, Cohen, & Brennan, 1990)
159	(Raninen, Vanni, Hyvarinen, & Nasanen, 2007)
161	(Reinhard et al., 2005)
162	(Romano et al., 2008)
163	(Rondot, Odier, & Valade, 1992)
164	(Rossi et al., 1990)
165	(Roth et al., 2009)
166	(Rothschild & Streifler, 1952)
167	(Sabel et al., 2004)
168	(Sahraie et al., 2010)
169	(Sahraie et al., 2006)
170	(Sahraie, Trevethan, & MacLeod, 2008)
171	(Saj, Honore, Richard, Bernati, & Rousseaux, 2010)
172	(Savino, Paris, Schatz, Orr, & Corbett, 1978)
173	(Savir, Michelson, David, Mendelson, & Najenson, 1977)
174	(Schadow et al., 2009)
175	(Scharli, Harman, & Hogben, 1999)
176	(Schmielau & Wong, 2007)

177 (Schoepf & Zangemeister, 1993)
178 (Schreiber et al., 2006)
179 (Schuett et al., 2008)
180 (Schulte et al., 1999)
181 (Serafeti.Ea, 1969)
182 (D. T. Smith, Lane, & Schenk, 2008)
183 (J. L. Smith, 1962)
184 (Spitzyna et al., 2007)
185 (Stoerig, Zontanou, & Cowey, 2002)
186 (Suzuki et al., 2008)
187 (Szlyk et al., 1993)
188 (Szlyk et al., 2005)
189 (Tant, Brouwer et al., 2002)
190 (Tant, Cornelissen et al., 2002)
191 (Tant, Kuks et al., 2002)
192 (Tiel & Kolmel, 1991)
193 (Toepfer, Kasten, Guenther, & Sabel, 2008)
194 (Traccis, Puliga, Ruiu, Marras, & Rosati, 1991)
195 (Trauzettel-Klosinski, 1997)
196 (Trauzettel-Klosinski & Brendler, 1998)
197 (Trauzettel-Klosinski & Reinhard, 1998)
198 (Trobe et al., 1973)
199 (Vallar, Sandroni, Rusconi, & Barbieri, 1991)
200 (Van der Stigchel, Nijboer, Bergsma, Abegg, & Barton, 2010)
201 (Van der Wildt & Bergsma, 1997)
203 (Vaphiades, Celesia, & Brigell, 1996)
204 (Vliegen & Koch, 1974)
205 (Vola, 1990)
206 (Wagenbreth et al., 2010)
207 (Walker, Mannan, Maurer, Pambakian, & Kennard, 2000)
208 (Warren, 2009)
209 (Warrington, 1962)
210 (Watanabe et al., 2007)
211 (Webster et al., 1984)
212 (Weil & Nosik, 1952)
213 (Wessinger, Fendrich, & Gazzaniga, 1999)
214 (Wildberger, Vanlith, Wijngaarde, & Mak, 1976)
215 (Williams & Gassel, 1962)
216 (Wohl, Kattah, Kolsky, Alper, & Horton, 1991)
217 (Wood et al., 2009)
218 (Wood et al., 2011)
220 (Younge, 1976)
221 (Zangemeister, Meienberg, Stark, & Hoyt, 1982)
222 (Zangemeister, Oechsner, & Freksa, 1995)
223 (Zhang et al., 2006a)
224 (Zhang et al., 2006b)
225 (Zhang, Kedar, Lynn, Newman, & Biousse, 2006c)
226 (Zihl, 1995a)
227 (Zihl, 1995b)
228 (Zihl, 1999)
230 (Zihl et al., 1984)
231 (Zihl et al., 2009)
232 (Zihl & Von Cramon, 1985)
233 (Zihl et al., 1977)

Numbers match the reference numbers in the paper as published in Survey of Ophthalmology.

4

Difficulties in daily life reported by patients with homonymous visual field defects

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Brouwer, W. H., & Tucha, O. (2015). Difficulties in daily life reported by patients with homonymous visual field defects. *Journal of Neuro-Ophthalmology, 35*, 259-264.

ABSTRACT

Background: Homonymous visual field defects (HVFD) are common after postchiasmatic acquired brain injury and may have a significant impact on independent living and participation in society. Vision-related difficulties experienced in daily life are usually assessed using questionnaires. The current study 1) links the content of 3 of these questionnaires to the International Classification of Functioning, Disability and Health (ICF) and 2) provides analyses of vision-related difficulties reported by patients with HVFD and minimal comorbidities.

Methods: Fifty-four patients with homonymous hemianopia or quadrantanopia were asked about difficulties experienced in daily life because of their HVFD. This was performed during a structured interview including 3 standardized questionnaires: National Eye Institute Visual Functioning Questionnaire, Independent Mobility Questionnaire, and Cerebral Visual Disorders Questionnaire. The reported difficulties were linked to the ICF according to the ICF linking rules. Main outcome measures were presence or absence of experienced difficulties.

Results: The ICF linking procedure resulted in a classification table that can be used in future studies of vision-related difficulties. Besides well-known difficulties related to reading, orientation, and mobility, a high proportion of patients with HVFD reported problems that previously have not been documented in the literature, such as impaired light sensitivity, color vision, and perception of depth.

Conclusions: A systematic inventory of difficulties experienced in daily life by patients with HVFD was performed using the ICF. These findings have implications for future study, assessment and rehabilitation of patients with HVFD.

INTRODUCTION

It has been estimated that homonymous visual field defects (HVFD) occur in 89% of patients with acquired postchiasmatic brain damage (Zihl, 2011). The most common form of HVFD is homonymous hemianopia. Estimated percentages of homonymous hemianopia among stroke patients range from 8% to 31% (Feigenson et al., 1977; Gilhotra et al., 2002). HVFD can have far-reaching negative effects on both general and vision-related quality of life (Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010). HVFD has been mainly associated with difficulties in reading, orientation and mobility (Chen et al., 2009; Gassel & Williams, 1963b; Papageorgiou et al., 2007; Trobe et al., 1973; Warren, 2009; Zihl, 1995b; Zihl, 2011). De Haan et al. (De Haan, Heutink, Melis-Dankers, Tucha, & Brouwer, 2014, chapter 3) pointed out that only a small percentage of studies on HVFD have focused on the consequences of HVFD on daily activities and participation in society.

In this study, a systematic inventory was performed on the difficulties experienced in daily life by patients with HVFD. Although several studies have reported on a number of difficulties caused by HVFD, the results were not based on systematic exploration, or resulted from very small patient groups or patients with other physical impairments. In our study, patients with HVFD had minimal comorbidities and to minimize bias from previous studies or clinical experience, a predefined classification system (International Classification of Functioning, Disability and Health; ICF) was used. A better understanding of the difficulties experienced in daily life by patients with HVFD hopefully will lead to better assessment and treatment methods.

METHODS

Participants

Patients were recruited from Royal Dutch Visio and Bartiméus, the 2 largest centers for rehabilitation for blind and partially sighted people in the Netherlands. Between 2010 and 2012, 373 patients suspected of having HVFD applied for rehabilitation at these institutes. Patients were subjected to extensive and standardized ophthalmologic and neuropsychological testing. In order to be included in the study, a HVFD was required. Time since origin of the field defect had to exceed 5 months, minimizing chances for spontaneous recovery of the field defect. Patients were excluded if visual acuity was ≥ 20/40 or if they had impaired ocular motility. Further exclusion criteria were symptoms of neglect, memory problems, depression, anxiety disorder, mini-mental state examination score < 24 or disorders of visual perception including visual spatial perception, visual object recognition, visual attention, or visuoconstruction.

Fifty-four patients met inclusion criteria and consisted of 35 men and 19 women with a mean age of 56 years (range, 27-75 years). In 37 patients, the HVFD was left-sided and 17 right-sided. The field defects existed for 20 months on average (range, 5-122 months). Eleven patients had a quadrantanopia (10 left-sided and 1 right-sided), whereas the remaining 43 cases had a hemianopia. Causes of the HVFD were ischemic stroke (*n* = 39), hemorrhagic stroke (*n* = 6), traumatic brain injury (*n* = 3), penetrating head trauma (*n* = 1), tumor resection (*n* = 1), extirpation of arteriovenous malformation with postoperative hemorrhage (*n* = 1), or combined etiology (*n* = 3).

All patients provided written informed consent. The Medical Research Ethics Committee of the University Medical Center Groningen approved the study. The study was performed in accordance with the 2008 Declaration of Helsinki.

Procedure and materials

Patients were examined individually during a structured interview. The assessment began with an open-ended request to name the difficulties they experienced in daily life because of their HVFD. Next, the effect of the HVFD on an extensive set of different situations was assessed using 3 standardized questionnaires. The Visual Functioning Questionnaire (NEI-VFQ-25) (Mangione et al., 2001) consists of multiple choice questions concerning the influence of visual impairment on several health-related domains, including emotional well-being, social functioning, and tasks related to daily visual functioning. With the Independent Mobility Questionnaire (IMQ) (Turano, Geruschat, Stahl, & Massof, 1999), the perceived ability for independent mobility despite visual impairment is evaluated. Patients rated on 5-point scales the amount of difficulty they experience in 35 mobility situations. In the second portion of the IMQ, the respondent is asked about mobility-related behavior, such as falling, use of mobility aids, and medication usage. The first part of the Cerebral Visual Disorders (CVD) questionnaire consists of 9 questions to assess the presence or absence of vision-related problems (Kerkhoff, Schaub, & Zihl, 1990). In the second part, respondents are asked to indicate on 5-point scales how much difficulty is experienced with 12 particular activities (Tant, 2002). The CVD contains questions not only on mobility and reading but also on other vision-related problems, such as perception of depth and colors, light sensitivity, and visual hallucinations. The combination of

Table 4.1. steps in the process of conversion and analysis.

Step 1: analysis of reported difficulties
Spontaneously reported difficulties
• Linking every spontaneously reported complaint to one or more ICF codes
• Calculating per ICF code how many patients report at least one problem in this category
Standardized questionnaires
• Linking every item to one or more ICF codes
• Converting scaled scores into dichotomous scores (absence or presence of the problem the item refers to)
• Calculating per ICF code how many patients report presence of a problem on at least one of the items in this category
Step 2: in-depth analysis
Standardized questionnaires
• Examining on the item level the percentages of patients reporting the presence of a problem. This was done for problems that appeared less directly related to missing half of the visual field.

these questionnaires enables extensive examination of a wide range of functions, activities, and participation. Since reading difficulties are common in patients with HVFD, the questionnaires were administered in oral interviews.

Step 1: Analysis of reported difficulties

The process of conversion and analysis are listed in Table 4.1.

Linking the reported difficulties to the ICF

Since the 3 questionnaires in total contained 102 questions, categorization of the items of these questionnaires, as well as the answers to the open-ended questions, was necessary for an accessible overview of the reported difficulties. Several methods for categorizing items or concepts have been used previously. Such classifications were often based on face validity or common sense and sometimes descriptions of how categories were constructed were completely missing. Although these methods can be very effective to answer certain research questions, they can easily be subject to bias.

To keep an unbiased objective approach in evaluating the reported difficulties, we applied a predefined classification system as a reference framework. The ICF (World Health Organization, 2001), as developed by the World Health Organization, has been used in numerous studies (Bruyere, Van Looy, & Peterson, 2005; Cerniauskaite et al., 2011; De Haan et al., 2014; Fayed, Cieza, & Bickenbach, 2011). In the ICF, concepts related to the health are categorized in body functions and structures, activities and participation, as well as environmental factors and personal factors. These components are further structured in domains and categories, resulting in unique codes for individual concepts.

In our study, 3 investigators working in the field of visual perception and familiar with the ICF model independently determined the concepts included in the questions and answers. Each concept was linked to the most precise ICF code according to the guidelines by Cieza et al. (2005) using the digital ICF browser (http://apps.who/int/classifications/icfbrowser). When comparisons of the 3 classifications revealed differences, an attempt was made to reach consensus. If this failed, a fourth evaluator was involved.

Table 4.2. Transformation of different rating scales into dichotomous scales. The item is rated as problem present in case one of the bold options is chosen by the participant. If this is not the case then the item is rated as problem absent.

Visual Functioning Questionnaire (NEI-VFQ-25)	
Item 1	(1) excellent, (2) very good, (3) good, **(4) fair, (5) poor**
Item 2	(1) excellent, (2) good, (3) fair, **(4) poor, (5) very poor, (6) completely blind**
Item 3	(1) none of the time, (2) a little of the time, **(3) some of the time, (4) most of the time, (5) all of the time**
Item 4	(1) none, (2) mild, **(3) moderate, (4) severe, (5) very severe**
Items 5-14,16,16a,A7,A9	(1) no difficulty at all, (2) a little difficulty, **(3) moderate difficulty, (4) severe difficulty, (5) stopped doing this because of your eyesight**, (6) stopped doing this for other reasons or not applicable
Item 15c	(1) no difficulty at all, (2) a little difficulty, **(3) moderate difficulty, (4) extreme difficulty, (5) stopped driving mainly because of eyesight**
Item 17-19	**(1) all of the time, (2) most of the time, (3) some of the time**, (4) a little of the time, (5) none of the time
Item 20-25,A12,A13	**(1) definitely true, (2) mostly true, (3) not sure**, (4) mostly false, (5) definitely false
Item A1,A2	**(worst) 0 1 2 3 4 5** 6 7 8 9 10 (best)
Item A11ab	**(1) always, (2) most of the time, (3) often, (4) sometimes**, (5) never
Independent Mobility Questionnaire (IMQ)	
Item 1-35, 47,48	N/A, (1) no difficulty, (2) few difficulty, **(3) a little difficulty, (4) moderate difficulty, (5) extreme difficulty**
Item 36-39,43-45	**Yes**/No
Item 40	**(1) always, (2) usually, (3) sometimes**, (4) never
Item 41	Yes/**No**
Cerebral Visual Disorders questionnaire (CVD)	
Item 2-7,9	**Yes**/No
Item 8	Yes/**No**
Item 10A-L	(0) no problem, (1) rarely a problem, **(2) sometimes a problem, (3) often a problem, (4) most of the time a problem**

Spontaneously reported difficulties

The spontaneously reported problems on open-ended questions were grouped by ICF code. For every ICF code, the number of patients reporting at least 1 problem in this area was calculated.

Standardized questionnaires

Because the answer formats of the questionnaire items differed markedly, the different scales were converted into dichotomous scales. The cut-points for the dichotomous scales were based on the conversion rule that every answer stronger than “sometimes a problem” (or words with similar inclination, such as “a little difficulty”) was classified as “difficulty present” (Table 4.2). The items were then grouped by ICF code. Within every ICF code, the number of patients indicating at least one of the problems to be present was determined.

Step 2: In-depth analysis

After determining the number of patients reporting difficulties within the various ICF categories, a more in-depth examination was performed for problems that appear less directly

related to missing part of the visual field. In this analysis, the effect of age on the presence or absence of a reported difficulty was assessed (two-tailed independent samples t-tests). Only results with a *p*-value < .05 were reported.

RESULTS

Step 1: Analysis of reported difficulties

Linking the reported difficulties to the ICF

Classifying the reported difficulties according to the ICF linking rules (Cieza et al., 2005) resulted in 268 concepts for the open-ended question and 248 concepts for the standardized questionnaires. During the process of linking these concepts, in 4 out of 516 concepts, no unanimous decision was reached, and the fourth evaluator was involved in the decision process, resulting in agreement (Table e-1, available on request to author).

Eighty-seven concepts were found not to be covered by the ICF. In order to include these in the analysis, they were grouped based on common sense, resulting in a number of additional categories (Table 4.3). For the answers on the open-ended question, these additional categories were difficulties seeing objects or people in time due to incomplete visual overview, difficulty using the computer, misplacing or knocking over of objects on tables, difficulty choosing suitable positions when sitting together with a group, falling or catching oneself, being easily overstimulated, and bumping the head.

Spontaneously reported difficulties

Among the frequently reported problems were difficulties seeing objects or people in time resulting from incomplete visual overview, as well as problems with orientation, way finding, and mobility (walking around obstacles or people, cycling or driving a car). Reading problems included finding the beginning of the next line or limited endurance. Other activities often experienced as problematic were placing or avoiding knocking over objects on tables, watching television, using the computer, shopping/doing groceries, and performing recreational activities. Patients with HVFD also reported fatigue and emotional disturbances (that is, feeling frustrated, irritable, insecure, scared, or tense) because of their visual disorder. Environmental factors frequently reported to cause difficulties were unfamiliar surroundings, crowded areas, darkness, or inclement weather.

Patients spontaneously reported several activities to be problematic that were not in the questionnaires. These included use of a computer (*n* = 10), riding a bicycle (*n* = 7), placing or avoiding knocking over objects (*n* = 6), writing (*n* = 3), cooking (*n* = 2), doing housework (*n* = 1), and following conversations (when sitting at an unfavorable position at a table; *n* = 2). Patients reported increased fatigability (*n* = 7), difficulty multitasking (*n* = 2), and trouble seeing contrasts (*n* = 1).

Standardized questionnaires

Table 4.3 shows the number of patients who reported problems per ICF category. The results confirm the findings of previous studies that patients with HVFD experience difficulty with finding objects, reading, and mobility. HVFD had a significant impact on participating in society, as the majority of patients reported difficulty with recreation and leisure activities, such as

Table 4.3. Results from the three standardized questionnaires in ICF terms: number and percentage of patients that rated at least one item in the category as problematic. The total number of patients having answered these items is put between parentheses when different from 54. The last column shows the number of items in the questionnaires referring to the category.

	N (total)	%	N items
BODY FUNCTIONS	54	100	49
b1 MENTAL FUNCTIONS	53	98	13
b114 Orientation functions	35	65	5
b1141 Orientation to place	35	65	5
b152 Emotional functions	51	94	6
b156 Perceptual functions	29	54	2
b1565 Visuospatial perception	11 (53)	21	1
b2 SENSORY FUNCTIONS AND PAIN	54	100	41
b210 Seeing functions	54	100	39
b2100 Visual acuity functions	23	43	1
b21002 Binocular acuity of near vision	23	43	1
b2102 Quality of vision	47	87	9
b21020 Light sensitivity	45	83	7
b21021 Colour vision	11 (53)	21	1
b21023 Visual picture quality	22	41	1
b220 Sensations associated with the eye and adjoining structures	11	20	2
b280 Sensation of pain	11	20	2
b2801 Pain in body part	11	20	2
ACTIVITIES AND PARTICIPATION	54	100	75
d1 LEARNING AND APPLYING KNOWLEDGE	45	83	8
d110 Watching	30	56	3
d166 Reading	43	80	5
d2 GENERAL TASKS AND DEMANDS	52	96	4
d210 Undertaking a single task	52	96	4
d2102 Undertaking a single task independently	52	96	4
d4 MOBILITY	54	100	51
d450 Walking	53	98	30
d4502 Walking on different surfaces	27 (53)	51	1
d4503 Walking around obstacles	53	98	15
d455 Moving around	31	57	6
d4551 Climbing	31	57	6
d460 Moving around in different locations	46	85	11
d4600 Moving around within the home	22	41	3
d4601 Moving around within buildings other than home	36	67	4
d4602 Moving around outside the home and other buildings	43	80	3
d470 Using transportation	21	39	2
d4702 Using public motorized transportation	21	39	2
d475 Driving	43 (47)	91	4
d4751 Driving motorized vehicles	43 (47)	91	4
d5 SELF-CARE	6	11	1
d540 Dressing	6	11	1
d6 DOMESTIC LIFE	52	96	3
d620 Acquisition of goods and services	52	96	3
d6200 Shopping	52	96	3
d7 INTERPERSONAL INTERACTIONS AND RELATIONSHIPS	11	20	1
d720 Complex interpersonal interactions	11	20	1
d7203 Interacting according to social rules	11	20	1
d8 MAJOR LIFE AREAS	5 (23)	22	2
d820 School education	1 (2)	50	1
d850 Remunerative employment	4 (22)	18	1

	N (total)	%	N items
d9 COMMUNITY, SOCIAL AND CIVIC LIFE	36	67	4
d920 Recreation and leisure	36	67	4
d9201 Sports	28	52	1
d9202 Arts and culture	20	37	1
d9204 Hobbies	23	43	1
d9205 Socializing	15	28	1
ENVIRONMENTAL FACTORS	54	100	20
e1 PRODUCTS AND TECHNOLOGY *	53	98	3
e110 Products or substances for personal consumption	51	94	1
e1101 Drugs (note of author: this refers to medication)	51	94	1
e120 Products and technology for personal indoor and outdoor mobility and transportation	11	20	1
e1201 Assistive products and technology for personal indoor and outdoor mobility and ransportation	11	20	1
e125 Products and technology for communication	21	39	1
e1251 Assistive products and technology for communication	21	39	1
e2 NATURAL ENVIRONMENT AND HUMAN-MADE CHANGES TO ENVIRONMENT	49	91	14
e240 Light	48	89	13
e2400 Light intensity	48	89	13
NOT DEFINABLE	18	33	2
Not definable-general health	18	33	2
NOT COVERED			
Difficulties seeing objects or people in time due to lack of a complete visual overview	51	94	6
Falling	35	65	2
Seeing how people react to things you say	10	19	1
Forced to rely too much on what other people tell me	11	20	1
Entertaining friends and family in your home	13	24	1
Perception of ascending or descending stairwells	24 (53)	45	2

Note: The ICF linking rules prescribe that concepts should be linked to the most precise ICF category. For example, while the concept present level of travel is linked to d4 (mobility), the concept car driving is linked to the more precise level d4751 (driving motorized vehicles). In Table 4.3, the car driving then is counted on level d4751, but also on levels d475 and d4.

*Numbers for Environmental Factors - 1.Products and technology are about whether the products are used, instead of whether use of these products is rated as problematic.

participation in sports, arts and culture, hobbies, and social events.

The ICF specifies 9 domains within the level of activities and participation. On average, patients reported difficulties in 5 (range 2-8) different domains. The number of domains affected was correlated negatively with age (r = -.38, p = .005). Younger patients reported difficulties in more domains than older patients. Time since onset of the HVFD was neither related to age (r = -.14, p = .312) nor to the number of domains in which difficulties were experienced (r = .23, p = .099). On average, women experienced difficulties in more domains of activities and participation than men (t(52) = -3.20, p = .002, mean difference 1.1 domain). Neither side of field defect (t(52) = 1.32, p = .191) nor type of field defect (hemianopia vs quadrantanopia; t(52) = 0.01, p = .992) was significantly related to the number of domains affected. Comparisons for gender, side of field defect, and type of field defect should be interpreted with caution because of uneven sample sizes.

Step 2: In-depth analysis

It was more problematic to link some repeated problems to missing a portion of the visual field. These were analyzed in more depth.

Light sensitivity

The majority of patients (94%) rated at least 1 item on the function light sensitivity (b21020) or the environmental factor light intensity (e2400) as problematic. Fifty-two percent of patients reported that everything seemed darker or that more light was needed when reading. However, 54% reported that they were now more blinded by bright lights. It appeared that 30% of patients experienced both of these problems concurrently. Walking in high glare areas was rated as problematic in 75% of cases, whereas 80% experienced problems walking, driving, or going down steps in dimly lit or dark areas. Combining all questions related to light sensitivity showed that 76% patients experienced problems with bright lights or high glare areas, as well as having increased difficulty seeing in dimly lit or dark areas. Difficulty adjusting to changes in light intensity, for example, when moving from indoor to outdoor, was reported by 56% of patients.

Color vision

Twenty-one percent of patients responded to the question on color vision (b21021) that colors did not seem as bright as before their HVFD.

Perception of depth

One patient elaborated on the open-ended question that perception of depth, distance, and velocity were disturbed. When all patients were asked whether they experienced problems estimating the height of the next step when using stairs, 21% agreed.

Negative feelings and thoughts

The results revealed that HVFD in most patients entailed negative feelings and thoughts (b152). In response to the open-ended question, 35% of patients experienced feelings of insecurity in unknown or busy surroundings or during walking, cycling, or driving. As indicated by the standardized questionnaires, 74% of patients reported worrying about their eyesight at least some of the time (28% most of time, 2% all the time). Half of the patients (50%) experienced feelings of frustration about their eyesight. Worries about doing things because of their eyesight that will embarrass oneself or others were reported by 31%. Eighty-four percent reported to be irritable because difficulties with vision. Fear of falling was reported by 44%. Sixty-five percent felt unsatisfied with their current ability to travel, and these participants were significantly younger compared to the participants reporting to be satisfied with their traveling abilities ($t(50.4) = -2.341$, $p = .023$). Regarding physical sensations, 20% of the patients reported pain or discomfort in or around the eyes, preventing them to do the things they wanted to do (b220, b280).

Independence

The majority of patients reported that the HVFD restrained them in performing activities without help from others (d2102). Seventy-two percent indicated that they needed or received an increased amount of help from others because of their visual impairment. Seventy percent felt restricted in walking independently, and 44% indicated that they rarely left the house without someone to accompany them. Those that asked someone to accompany them were found to be significantly younger ($t(52) = -3.391$, $p = .001$).

DISCUSSION

We conducted a systematic inventory of the difficulties that 54 patients with HVFD experienced in daily life, expressed in terms of the ICF. To this end, 3 questionnaires often used in studies of visual impairments (NEI-VFQ-25, IMQ, and CVD) were linked to the ICF. Not surprisingly, patients reported difficulties due to deficits in their visual environment and associated feelings of frustration and insecurity. They also reported difficulties that did not seem directly related to missing portions of the visual field, such as disturbed light sensitivity, color perception, and depth perception. Conceivably, the reported difficulties were not related to HVFD specifically but might be a more general result of brain damage. Younger patients described problems in more domains and were less satisfied with their ability to travel independently, compared with older adults. This association was not explained by a confounding effect of time since onset. Possibly, younger patients performed a wider range of activities before onset of the HVFD, making the impact of this deficit more striking.

To the best of our knowledge, there are no other systematic studies of the difficulties experienced by patients with HVFD (see chapter 3), although there are reports describing a more limited scope of difficulties. Most often, these have dealt with patients' complaints of reading, orientation, and mobility-related activities (Chen et al., 2009; Gassel & Williams, 1963b; Papageorgiou et al., 2007; Trobe et al., 1973; Warren, 2009; Zihl, 1995b; Zihl, 2011). Our results support these findings. Previous reports have indicated that patients with HVFD experience impaired general and vision-related quality of life (Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010). We also found that patients with HVFD frequently experienced difficulties with recreation and leisure activities, negative feelings and thoughts, and a feeling of decreased independence. In contrast to our data suggesting that younger patients experience more difficulties in daily life compared with older individuals, other studies did not find an association between age and quality of life (Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010) or found poorer quality of life in older patients (Gall, Mueller, Gudlin et al., 2008; Gall et al., 2009). There are no other reports of problems with light sensitivity, color vision, and depth perception, but our study indicates that these problems are frequently experienced by patients with HVFD.

Our aim was not to determine the precise percentage of patients reporting a certain problem but to become aware of the full range of difficulties experienced by patients with HVFD. However, we are aware of the limitations of our report. To begin with, the ICF did not include every conceivable concept. In linking all concepts addressed in the questionnaires to the ICF, 87 (17%) were not covered by the ICF, which was mainly caused by a small number of concepts encountered with high frequency. Next, to enable quantitative assessment, data

were summarized as presence or absence of a problem of at least one of the items within an ICF category. By converting ordinal scales into dichotomous scales, information of the degree of difficulty was lost.

We recognize potential sources of bias affecting generalizability of the results. The different sample sizes for men vs women, left vs right-sided HVFD and quadrantanopia vs hemianopia might be the result of selection bias, possibly related to the exclusion criteria regarding comorbidity. Patients with additional comorbidities, such as neglect, low visual acuity, or impaired oculomotor functioning, might experience a different range of difficulties in daily life. The reported difficulties cannot be assumed to fully generalize to patients not requesting rehabilitation. The current study was performed in the Netherlands. Other countries might provide different challenges for patients with HVFD. Another possible source of bias relates to the answers of the participants. They spontaneously reported a number of problems that were not included in the standardized questionnaires. However, participants did experience problems mentioned in the standardized questionnaires that they had not spontaneously reported. This might suggest an acquiescence bias, possibly leading to false positives on the standardized questionnaires. Nevertheless, acquiescence bias would not account for the relative differences between frequencies of reported difficulties. A final possible source of bias regarding the standardized questionnaires may have come from the fact that not every ICF category was assessed by the same number of items (Table 4.3).

Based on our results, recommendations can be made for professionals involved in assessment of patients with HVFD. In addition to the well-known difficulties experienced by patients with HVFD, a number of additional impairments deserve attention, including disturbed light sensitivity, color perception, and depth perception. These problems might otherwise be overlooked when assessing the patient, as they may not be spontaneously reported. It would be useful to apply both open-ended questions, as well as standardized questionnaires, to this patient population because they were found to be complementary. These recommendations may lead to more effective and appropriate counseling and rehabilitation.

Acknowledgements

Special thanks to the staff of the Royal Dutch Visio and Bartiméus involved in the recruitment of participants. The authors gratefully acknowledge Christina Cordes, MSc and Stefanie de Vries, MSc of the Department of Clinical and Developmental Neuropsychology at the University of Groningen, the Netherlands, for their support in linking the questionnaires to the ICF, and Fréderique Bambach, MSc for her contribution to the data collection and analyses.

5

Car driving performance in hemianopia: an on-road driving study

De Haan, G. A., Melis-Dankers, B. J., Brouwer, W. H., Bredewoud R. A., Tucha, O., & Heutink, J. (2014). Car driving performance in hemianopia: an on-road driving study. *Investigative Ophthalmology & Visual Science, 55*, 6482-6489.

ABSTRACT

Purpose: To study driving performance in people with homonymous hemianopia (HH) assessed in the official on-road test of practical fitness to drive by the Dutch driver's licensing authority (CBR).

Methods: Data were collected from a cohort (January 2010–July 2012) of all people with HH following the official relicensure trajectory at Royal Dutch Visio and the CBR in the Netherlands. Driving performance during the official on-road tests of practical fitness to drive was scored by professional experts on practical fitness to drive, using the visual impairments protocol and a standardized scoring of visual, tactical and operational aspects. Age ranged from 27 to 72 years (M = 52, SD = 11.7) and time since onset of the visual field defect ranged from 6 to 41 months (M = 15, SD = 7.5).

Results: Fourteen (54%) participants were judged as fit to drive. Besides poor visual scanning during driving, specific tactical, and operational weaknesses were observed in people with HH that were evaluated as unfit to drive. Results suggest that judgement on practical fitness to drive cannot be based on solely the visual field size. Visual scanning and operational handling of the car were found to be more impaired with longer time not driven, while such an effect was not found for tactical choices during driving.

Conclusions: Training programs aimed at improving practical fitness to drive in people with HH should focus on improving both visual scanning, as well as driving aspects such as steering stability, speed adaptation, and anticipating environmental changes.

INTRODUCTION

Driving a car is an essential way of transportation for the majority of people in industrialized countries and forms an important prerequisite for independent daily life, but opportunities for driving may be limited in the presence of visual field disorders. Although in most countries the minimum horizontal visual field size required for driving a car is set to 120 degrees, in some countries, like the Netherlands, smaller field sizes are not an absolute contra-indication. Aiming at an inclusive society with equal opportunities for disabled people, the Dutch government allows people under strict conditions to prove practical fitness to drive despite an impairment. In these cases licensing is strictly regulated, including specialist medical assessment and a requirement to be judged fit to drive in an official on-road test of practical fitness to drive where the driver must demonstrate that (s)he adequately compensates the field defect (Brouwer & Ponds, 1994; Paparella, Piccoli, Brouwer, & Hunter, 2009). This procedure is allowed under the European Union (EU) driving license directive (European Parliament, Council of the European Union, 2006) where it states in Annex III, paragraph 6.1: "Driving licenses shall not be issued or renewed if during the medical examination, it is shown that the horizontal field of vision is less than 120^{o}, apart from exceptional cases justified by a favourable medical opinion and a positive practical test".

Practical fitness to drive is defined as being able to drive safely and smoothly (i.e., driving without abrupt changes in speed and course), taking impairments into account (i.e., compensating for the impairment). Where medical fitness to drive refers to impairments on the body level (i.e., visual field size), practical fitness to drive refers to driving performance on the activity level. A person with a visual impairment is considered "fit to drive" if driving

performance in a range of road and traffic situations falls within the normal range of sighted drivers, and if no impairment-related driving errors are made. Where a regular driving exam focuses on driving skills, the test of practical fitness to drive evaluates the ability to adapt driving skills and driving behavior in case of impairments (Brouwer & Ponds, 1994; Paparella et al., 2009).

The system as applied in the Netherlands is followed with high interest by other European countries. In some countries skepticism is widely prevalent about driving abilities in people with visual field defects and some countries are considering to copy the Dutch system. Publication of the results from the Dutch system is therefore required and now provided. Not only is it relevant to present how many people with visual field defects are judged as fit to drive; it is also highly important to know about the errors these people tend to make so that training methods and technical aids can be developed.

A frequently occurring visual field defect for which the Dutch government issued official regulations is homonymous hemianopia (HH). Homonymous hemianopia is the most common form of homonymous visual field defects (HVFD) and refers to a loss of perception for either the left or the right half the visual field, affecting both eyes, resulting from postchiasmatic brain injury. Homonymous hemianopia is one of the most frequent visual disorders following acquired postchiasmatic brain damage, such as stroke (estimations of HH among stroke 8%-31%) (Feigenson et al., 1977; Gilhotra et al., 2002).

A number of studies performed in the Netherlands (Brouwer, Busscher, & Tant, 2013; Tant, Brouwer et al., 2002), Canada (Racette & Casson, 2005), and the United States (Elgin et al., 2010; Parker et al., 2011; Wood et al., 2009; Wood et al., 2011) have examined on-road driving performance in people with HH. These studies suggest that people with HH use several viewing strategies when driving, but do not always apply these in a consequent or effective way. Other frequently observed problems are difficulties with gap judgement, driving too slow or fast, frequent sudden braking, poor reaction to unexpected events, and problems regarding steering stability and adequate positioning on the road. Nevertheless, some people with HH were found to drive safely despite their visual impairment.

Traffic infrastructure and mix of transport modalities in the European Union differs significantly from those in North America (Kooijman et al., 2008). For example, the road systems in European towns and cities tend to have more narrow roads and irregular intersections than the typical American checkerboard layout. In addition, speed differences between road users tend to be larger in Europe, where there are often more bicycles, trams, and other slow vehicles on the road and where speed limits for cars may be higher. European countries are therefore reluctant to simply apply the results from American studies to the European situation.

Knowledge about driving performance of people with HH in European countries is therefore highly relevant for clinical and legal decision-making concerning driving in Europe. Over a decade ago, Tant and colleagues (Tant, Brouwer et al., 2002), delivered significant groundwork by showing that in a selected group of people with HH, some (4 of 28) appeared fit to drive. This has led to an expanding number of people with HH applying for the relicensure procedure at the Dutch driver's license authority (CBR). Royal Dutch Visio, Centre of Expertise for blind and partially sighted people, cooperates with the CBR in guiding and assessing these

people. The current study examines the outcomes from a cohort (January 2010-July 2012) of all people with HH following the official route as now established by the CBR and Royal Dutch Visio.

METHODS

Participants

Between January 2010 and July 2012, 86 people with HH applied for help at Royal Dutch Visio, Centre of Expertise for blind and partially sighted people, in preparing for the assessments of fitness to drive.

To determine whether these people met the legal requirements for driving (Box 5.1), extensive and standardized ophthalmologic and neuropsychological testing was performed. The following visual functions were assessed: visual acuity (Early Treatment Diabetic Retinopathy Study 2000 letter chart), refraction, reading acuity (LEO-charts), monocular and binocular Goldmann as well as monocular Humphrey 10-2 perimetry, eye and head motility, Vistech contrast sensitivity and image distortion (Amsler grid). Visual perception and (neuro)psychological functioning were assessed with the Mini Mental State Examination, Visual Object and Space Perception, Balloons, Trail Making Test, Eight word test, Drawings, Line Bisection, Rey Complex Figure Test, Hospital Anxiety and Depression Scale and behavioral tests for optic ataxia and sticky fixation. Assessments were performed at regional departments of Visio and outcomes were evaluated by an independent national team (GAdH, BJMM-D, JH) in consultation with the Dutch driver's license authority (RB).

Sixty people did not meet the legal requirements. The most frequent reasons for not meeting the requirements were a horizontal visual field larger than 120^{o} or comorbidity (visual perception disorders, cognitive disorders, unstable tumor growth, recent additional stroke, Alzheimer's disease, and/or unstable cardiac situation). The characteristics of the remaining 26 participants are presented in Table 5.1. The visual field defect resulted from postchiasmatic brain damage caused by infarction (n = 18), hemorrhage (n = 2), traumatic brain injury (n = 1), tumor resection (n = 1), extirpation of arteriovenous malformation with postoperative hemorrhage (n = 1) and combined etiology (n = 3). Although people with HH are not allowed to drive by law unless they have been judged fit to drive by the CBR, three participants were current drivers at time of the assessment.

All patients provided written informed consent. The study design was approved by the Medical Research Ethics Committee of the University Medical Center Groningen and performed in accordance with the 2008 Declaration of Helsinki.

Procedure

The 26 participants were assessed during a test of practical fitness to drive. Although all participants had a driver's license before the onset of the HH, proving that they had learned the driving skills previously, most participants were not current drivers. Participants were allowed to practice vehicle control in the unfamiliar test vehicle for one lesson at maximum. The driving instructor was explicitly told not to give any instructions on visual scanning during this driving lesson, since the interest of the study was to examine driving performance without visual training or instructions on viewing strategies. During the test of practical fitness to drive,

Table 5.1. Participant Characteristics.

	Fit to Drive, *n* = 14	Unfit to Drive, *n* = 12	Total, *n* = 26
Sex			
Men	10	8	18
Women	4	4	8
Side of HH			
Left-sided HH	9	12	21
Right-sided HH	5	0	5
Size of field defect (FFS)	66 (10.7)	57 (6.2)	62 (10.0)
Quadrantanopia	4	1	5
Hemianopia	10	11	21
Visual acuity	1.17 (0.18)	1.04 (0.29)	1.11 (0.24)
Contrast sensitivity*	2.07 (0.23)	2.15 (0.05)	2.11 (0.18)
Age			
Mean (*SD*)	52 (10.4)	52 (13.5)	52 (11.7)
Range	29-65	27-72	27-72
Time since onset of HH, mo			
Mean (*SD*)	14 (9.3)	15 (5.0)	15 (7.5)
Range	6-41	8-23	6-41
Driving experience, y			
Mean (*SD*)	31 (10.2)	32 (15.0)	32 (12.4)
Range	10-47	6-53	6-53
Time not driven, mo			
Mean (*SD*)	11 (10.8)	19 (17.5)	15 (14.6)
Range	0-41	8-73	0-73
Driving at time of assessment	3	0	3

Data for continuous variables are presented as mean (SD). FFS, Functional Field Score (American Medical Association, 2008).
*see Appendix 5.3

an expert on practical fitness to drive (DPR; Box 5.1) evaluated driving performance. Fifteen DPRs were involved in the current study. The on-road assessment took place in a car with dual control, allowing the DPR to apply the brakes and clutch from the passenger side in order to avert immediate danger, if required. The ride consisted of trajectories in urban areas, as well as more rural, suburban and highway routes and took approximately 45 minutes. For each participant, the DPR scored a standardized checklist (TRIP). Furthermore, a short additional report was written and a final decision was made about practical fitness to drive ("fit" or "unfit to drive").

Test Ride for Investigating Practical Fitness to Drive (TRIP)

The TRIP checklist is a list of 57 items reflecting different aspects of driving (Appendix 5.1) (Tant, Brouwer et al., 2002; Withaar, 2000). For each item, the DPR indicated whether the behavior was sufficient (3 points), doubtful (2 points), or insufficient (1 point). Because of their content, three items had different answer alternatives. "Lateral position on the driving lane" was rated as approximately in the middle (3 points), fluctuating (1 point), too much to the left (1 point), or too much to the right (1 point). The possible ratings for the item "following distance" were sufficient (3 point), long (2 points), or short (1 point). The item "choice of speed" was rated as average (3 points), slow (2 points), or fast (1 point).

Box 5.1. Legislation and procedure in the Netherlands.

According to the Dutch law, persons with impairments have to meet an extensive set of medical requirements in order to be considered for the on-road test of practical fitness to drive (Regeling Eisen Geschiktheid 2000.). For persons with HH, the requirements regarding visual functions are particularly relevant. The visual conditions that have to be met are (1) a horizontal visual field size of at least 90 degrees, (2) no other disorders that influence driving behavior and (3) a positive advice from an ophthalmologist. Furthermore, binocular best corrected visual acuity has to be at least 0.5 (6/12 or 20/40) and no oculomotor dysfunctioning is allowed. These rules apply to passenger cars only (group 1 licenses). For trucks and busses (group 2 licenses), the criteria are stricter and exclude individuals with HH altogether. Brain damage, as present in all persons with HH, increases the chance that cognitive impairments exist. In case of cognitive impairments, additional regulations apply (Regeling Eisen Geschiktheid 2000.). The on-road test of practical fitness to drive is employed to evaluate the impact of the visual and cognitive impairments on driving.

The Dutch driver's license authority (CBR) applies extensive and standardized protocols for evaluating practical fitness to drive in persons with functional impairments. In the Netherlands, 21 professional driving experts (DPRs) are employed and have been trained by the government to evaluate practical fitness to drive in persons with impairments. DPRs have received extensive education on medical impairments and how these could interfere with driving. Regarding the consequences of HH in particular, all DPRs received one day of additional training at Royal Dutch Visio. The professional conduct, working method and decision-making of the 21 DPRs are assessed and evaluated by two special coaches that ride along with the DPR on a regular basis. Although the coaches' task is to monitor high consistency between DPRs, no exact data on inter-rater reliability are provided by the government.

Each test of practical fitness to drive is conducted by one DPR, following official protocols. Since the DPR's task is to decide whether or not a person is fit to drive despite a particular impairment, he or she is informed about the nature of the impairment (e.g. side of the hemianopia). To assure that compensatory behavior (i.e. looking towards the blind side in order to perceive the relevant information there) is not only applied in situations triggering looking towards the blind periphery, such as busy crossroads, it is evaluated whether the participant continuously applies efficient viewing behavior in both complex situations as well as in quiet surroundings. During a test of practical fitness to drive the DPR scores different aspects of driving behavior using a standardized checklist (TRIP). In case a person is judged as fit to drive, a valid drivers' license is obtained.

Based on subsets of items, four subscores were calculated, in a similar way as performed by Tant, Brouwer and colleagues (2002). The visual subscale (VIS) was calculated by averaging 23 items related to visual scanning behavior. The operational subscale (OPER) was created by averaging nine items on operational actions, such as steadiness of steering and operating the brakes. The tactical subscale (TACT) was composed by averaging 15 items on tactical driving behavior, such as adapting speed and anticipating environmental changes. The average of three items regarding general impressions of "practical fitness to drive", "mechanical operation", and "traffic perception and traffic insight" brought forth the global subscale (GLOB).

Statistics

Data analysis was performed with SPSS (version 20; IBM Corp., Armonk, NY, USA). All tests were conducted two-sided. *P*-values less than .05 were considered significant and *p*-values between .05 and .10 suggestive for trends.

First, driving performance was analyzed for the total group of HH participants. The number of participants rated as fit to drive, as well as the average subscores and Spearman's correlations between subscores were calculated. The distributions of insufficient, doubtful and

sufficient ratings on the TRIP questionnaire were examined and a χ^2 test was conducted for the differences in distributions between the subscales.

Second, it was examined which aspects of driving behavior made that people were judged as unfit to drive. The differences in the average subscores (VIS, OPER, and TACT) between the fit and unfit drivers were analyzed with Mann-Whitney tests and effect sizes (Cohen's *d*) (Cohen, 1988). The percentages of sufficient ratings on the individual TRIP items were compared between the fit and unfit drivers. The additional reports were checked for interventions by the DPR.

Third, the influences of several participant characteristics on driving behavior were examined. Differences between fit and unfit drivers regarding continuous variables (age, visual field size, time since onset, years of driving experience, and/or time not driven) were analyzed with t-tests or, in case of nonnormality of data, Mann-Whitney tests. Relations between participant characteristics and TRIP subscores were analyzed by conducting Mann-Whitney tests for the dichotomous variables (sex, side of HH, hemianopia versus quadrantanopia) and Spearman's correlations (r_s) for the continuous variables (see above).

RESULTS

Driving performance

Fourteen (54%) participants were evaluated as fit to drive and regained a valid driver's license for a maximum of 5 years and for private use only. The average subscores are included in Table 5.2. High positive correlations were found between the TRIP subscales (all combinations: $r_s >$ .687, $p <$ .001, data not shown).

The TRIP ratings for the individual items are presented in Appendix 5.2 and summarized on subscale level in Table 5.3. The items of the VIS subscale were not significantly more often rated as insufficient or doubtful than the items of the OPER and TACT subscales (χ^2 two-tailed: p = .789). For all three subscales, several items were rated as insufficient or doubtful for a considerable number of participants, mainly related to viewing behavior in several situations, steering stability, speed adaptation, and anticipating changes in road and traffic situations (Appendix 5.2).

Driving aspects related to a negative evaluation of fitness to drive

All TRIP subscores were significantly lower for the unfit drivers than for the fit drivers (Table 5.2) with large effect sizes (Cohen, 1988) (VIS: 1.96, OPER: 1.44, TACT: 1.82). The differences in the number of 'sufficient' ratings between the fit and unfit drivers were largest for item 31 (perception and judgement during overtaking and passing by), 28 (anticipatory viewing behavior with regard to changing traffic situations), and 34 (tactical anticipation with regard to changing traffic situations). These items were rated as sufficient for 100% of the fit drivers versus 25% of the unfit drivers.

All the fit drivers had average subscores of at least 2.7 on all subscales (VIS, OPER, and TACT), while the unfit drivers received lower scores on at least one subscale (VIS < 2.7 in 10 cases; OPER < 2.7 in 7 cases, and TACT < 2.7 in 9 cases). However, one participant rated as unfit to drive scored higher than 2.8 on all three subscales. This participant received lower scores than any of the fit drivers on the items 13, 19, 31, 55, and 57 (items explained in Appendix 5.1).

Table 5.2. Average (SD) subscores from the on-road driving assessments, N = 26 participants.

	VIS	OPER	TACT	GLOB
Total, *N* = 26	2.59 (0.52)	2.71 (0.48)	2.66 (0.42)	2.50 (0.65)
Fit to drive, *n* = 14	2.92 (0.10)	2.97 (0.07)	2.92 (0.10)	3.00 (0.00)
Unfit to drive, *n* = 12	2.20 (0.53)	2.40 (0.58)	2.36 (0.44)	1.92 (0.52)
p-value [a]	<.001**	<.001**	<.001**	<.001**
LHH, *n* = 21	2.50 (0.54)	2.64 (0.52)	2.61 (0.45)	2.38 (0.67)
RHH, *n* = 5	2.95 (0.12)	2.98 (0.05)	2.88 (0.11)	3.00 (0.00)
p-value [b]	.034*	.105	.374	.049*
Hemianopia, *n* = 21	2.52 (0.55)	2.63 (0.52)	2.59 (0.43)	2.45 (0.66)
Quadrantanopia, *n* = 5	2.86 (0.23)	3.00 (0.00)	2.95 (0.12)	2.73 (0.60)
p-value [c]	.121	.034*	.019*	.374

Scales range from 1 to 3, higher scores indicate better performance. P-values for the differences between the groups are based on Mann Whitney tests.

* p < .05

** p < .001.

[a] comparison between fit and unfit drivers

[b] comparison between LHH and RHH

[c] comparison between hemianopia and quadrantanopia

Table 5.3. Distributions of ratings ("insufficient", "doubtful" and "sufficient") expressed in percentages and arranged by subscale and fitness to drive, N = 26 participants.

		Insufficient	Doubtful	Sufficient
VIS				
	Total, *N* = 26	14.9	12.8	72.3
	Fit to drive, *n* = 14	0.9	6.2	92.9
	Unfit to drive, *n* = 12	31.3	20.3	48.5
OPER				
	Total, *N* = 26	10.3	10.7	79.0
	Fit to drive, *n* = 14	0.0	3.2	96.8
	Unfit to drive, *n* = 12	22.2	19.4	58.3
TACT				
	Total, *N* = 26	11.1	13.1	75.8
	Fit to drive, *n* = 14	1.9	4.8	93.3
	Unfit to driven, *n* = 12	21.7	22.8	55.6
GLOB				
	Total, *N* = 26	20.5	11.5	67.9
	Fit to drive, *n* = 14	0.0	0.0	100.0
	Unfit to drive, *n* = 12	44.4	25.0	30.6

The additional reports showed that interventions in braking or steering by the DPR were necessary for 5 of 12 unfit drivers and for none of the fourteen fit drivers. For three unfit drivers it was explicitly reported that looking toward the blind side resulted in maladjusted driving behavior and an inappropriate position on the road. Scanning behavior of all 14 fit drivers was reported to be sufficient and not interfering with operational or tactical driving.

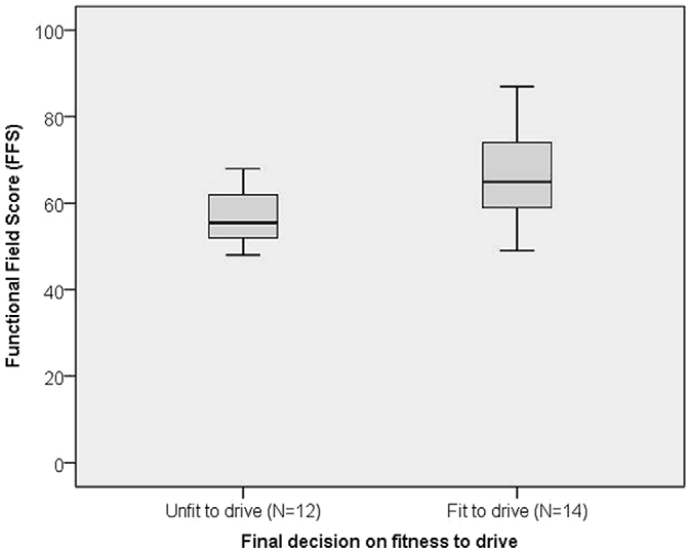


Figure 5.1. Boxplots of FFS categorized by fitness to drive. Interquartile ranges depicted.

Participant characteristics

Table 5.1 shows the differences in participant characteristics between fit and unfit drivers and Table 5.2 presents the correlations between participant characteristics and TRIP subscores. No evidence was found for effects of age, sex, and years of driving experience on the end-verdict (fit or unfit to drive) or the TRIP subscores. The only noteworthy finding for time since onset was a near-significant correlation with VIS (r_s = -.359, p = .072); the longer time since onset, the lower the evaluations of viewing behavior. A trend for a difference between the fit and unfit drivers was found in the number of months participants had abstained from driving (fit: M = 11.2, unfit: M = 19.3; p = .060). The three current drivers were all judged as fit to drive. The longer participants had not driven, the lower their scores on the VIS (r_s = -.474, p = .014), OPER (r_s = -.498, p = .010), and GLOB (r_s = -.490, p = .011) subscales (correlation with TACT failed significance, r_s = -.285, p = .159).

The visual field size was quantified in terms of Functional Field Score (FFS) (American Medical Association, 2008), a higher FFS meaning a larger remaining visual field. The fit drivers on average had a larger visual field (M = 66.1) than the unfit drivers (M = 56.6; p = .012). However, Figure 5.1 shows that there is no cut off point below which all participants are unfit to drive. The larger the visual field, the higher the VIS, OPER, and GLOB scores (VIS r_s = .521, p = .006; OPER r_s = .458, p = .019; GLOB r_s = .472, p = .015). Correlation with TACT failed significance (r_s = .340, p = .090).

All five right-sided hemianopia (RHH) participants were rated as fit to drive, while this was the case for only 9 of the 21 left-sided hemianopia (LHH) participants. The participants with RHH performed better than the LHH participants (Figure 5.2), as confirmed by significant differences in VIS and GLOB (Table 5.2). The relations between side of field defect and the other subscales (OPER and TACT) failed significance. These results have to be interpreted

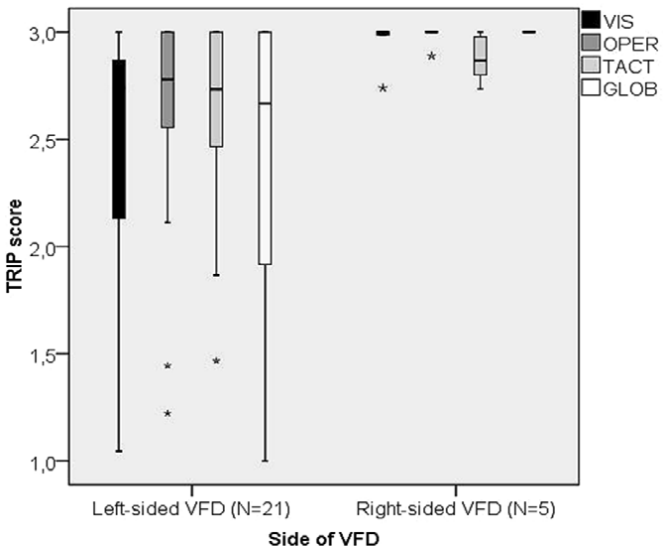


Figure 5.2. Boxplots of TRIP subscale scores split by side of field defect. Interquartile ranges depicted. *Outliers: cases with values more than 1.5 box lengths (interquartile range) from the lower edge of the box.

cautiously because of the different sample sizes. Furthermore, time not driven was shorter and visual field size larger for the participants with RHH, two variables found to be significantly associated with the subscores.

Problems maintaining an appropriate position on the road were only found for LHH participants. Positioning on the road (TRIP item 1) was evaluated as not sufficient in 7 of the 21 LHH participants (33%). Three of them drove too much to the right, one drove too much to the left, and the remaining three showed too much fluctuation in lateral position. Steadiness of steering (TRIP items 2-7) was evaluated as not sufficient in 11 LHH participants (52%). With regard to lane choice (TRIP items 8-11), eight LHH participants (38%) scored not sufficient, most often regarding lane choice when turning left.

DISCUSSION

Data were collected from a cohort (January 2010-July 2012) of all people with HH performing the official on-road test of practical fitness to drive as part of the official trajectory at Royal Dutch Visio and the CBR in the Netherlands. Fourteen (54%) people with HH were evaluated as fit to drive, against 14% to 77% in previous studies (Elgin et al., 2010; Tant, Brouwer et al., 2002; Wood et al., 2009; Wood et al., 2011). The different outcomes might be caused by differences in participant characteristics, selection, assessment procedures, as well as traffic conditions and regulations. As expected in a group of people with visual impairments, items regarding viewing behavior were often rated as insufficient. More interestingly, handling of the car and the choices made during driving were often rated insufficient as well. Items most often rated as insufficient or doubtful were mainly related to viewing behavior, steering stability, speed adaptation, and anticipation to changes in the environment. These difficulties are in

close agreement with the driving skills found to be affected in an earlier study using the TRIP questionnaire on people with HH (Tant, Brouwer et al., 2002).

In contrast to the previous European study by Tant, Brouwer and colleagues (2002), the number of fit drivers (n = 14) was roughly equal to the number of unfit drivers (n = 12), allowing for additional analyses of the differences between these groups that could not be performed by Tant. These analyses showed that observed difficulties with visual scanning during driving, as well as impaired tactical and operational driving performance were associated with the decision that someone is unfit to drive. Insufficient performance in each of these three driving aspects could be a reason for being judged as unfit to drive. Since vision is the main source of information-input during driving (Rockwell, 1972), driving with a visual field defect asks for extra efforts to perceive all necessary information. This may create time pressure and may constrain available attention capacities, resulting in difficulties with tactical and operational aspects of driving. This hypothesis is supported by the TRIP scores as well as the additional reports in the current study.

Although substantial parts of the results are in agreement with the results from previous studies, some differences are worth mentioning. A particular driving skill found to be impaired in people with HH is maintaining an adequate position on the road. While in the study of Tant, Brouwer and colleagues (2002) a problematic lateral deviation toward the right side was only found for some people with RHH and no deviation for people with LHH, Wood and colleagues (2011) found a tendency for LHH as well as RHH people driving too much to the unaffected, seeing side. In the present study, this was only found for LHH participants.

To our knowledge, this is the first study to include analyses of the time interval the participants have stopped driving. Earlier studies have found that current drivers were evaluated more often as safe to drive (Brouwer et al., 2013; Wood et al., 2009) and received higher scores on visual behavior during driving (Tant, Brouwer et al., 2002) than people who had stopped driving. In the present study, evidence was found for lower scores on the VIS, OPER, and GLOB subscales, but not the TACT subscale, with an increasing period of time not driven.

Some comments should be made with regard to the assessment procedure applied in the present study. The official on-road driving test is by definition a valid test to evaluate whether persons with impairments are fit to drive, since the evaluation takes place in the exact same situation that is being evaluated (driving on the road). Furthermore, the tests of practical fitness to drive were conducted by government-trained professional evaluators (DPRs) with a legal say on fitness to drive, in contrast to the previous American studies. However, high validity does not necessarily imply that measurements are reliable. Although all assessments were conducted according to a standardized protocol guaranteeing sufficient diversity in traffic conditions, reliability of assessments may have been negatively affected by the fact that the driving route could not be standardized across different regions. While interrater reliability of all DPRs is maximized by the education system including regular evaluations (Box 5.1) and the standardized assessment procedure including the TRIP questionnaire, exact data of the interrater reliability of the 15 DPR's participating in this study were not available. This forms a limitation to this study. In general, masked evaluators are preferred in observational studies. In case of our study the evaluators (DPRs) had to be informed about the nature of the visual

impairment (HH and affected side of visual field). One could argue that this may have led to a bias in their evaluations toward vision-related problems. However, the purpose of the on-road test of practical fitness to drive is to specifically evaluate whether the impairments lead to impairment-related driving errors. The risk that evaluations were based only on viewing behavior was minimized by the extensive training and reliability-checks of the DPRs and by using the TRIP that predefined specific operational and tactical aspects to be evaluated besides the visual aspects. Still, chances are that the results would have been different in case of completely masked evaluators.

Mobility plays a major role in independent living and participation in industrialized society and ceasing car driving has been associated with social isolation, depression, and decreased quality of life, among other negative consequences (Owsley & McGwin, 2010). Therefore, it is highly relevant that people with visual field defects are allowed to demonstrate their driving skills in a valid driving assessment, on the condition of positive evaluations of visual and (neuro)psychological functioning. For people judged as unfit to drive, applying such a careful test protocol is likely to increase their acceptation of and compliance with the final decision. The current legislation in the Netherlands states that for consideration for a test of practical fitness to drive, the horizontal visual field has to be at least 90^{o} (Regeling Eisen Geschiktheid 2000.). Different boundaries for a minimal required visual field size are applied in other countries. None of these values, including the values applied in the Netherlands, are based on scientific evidence or clear rationales (Owsley & McGwin, 2010). Although several studies have found evidence for people with HH being more impaired in car driving than people with quadrantanopia, no relation has been demonstrated between the extent of the horizontal visual field defect and driving performance (Elgin et al., 2010; Parker et al., 2011; Racette & Casson, 2005; Wood et al., 2009). In the current study, visual field size correlated positively with viewing behavior and operational handling during driving, but there was no indication for a cut-off below which all participants were unfit to drive. Until future research has found support for a certain threshold in terms of visual field size, policy makers could reconsider the criterion for a minimal horizontal visual field as a requirement for participation in a test of practical fitness to drive.

None of the participants had received training preceding the test of practical fitness to drive. The results provide suggestions for rehabilitation programs. Not only visual behavior was found to be affected in a substantial part of people with HH, but tactical and operational aspects as well. Training programs aiming at improving practical fitness to drive in people with HH should therefore not only focus on improving compensatory visual scanning (Bouwmeester et al., 2007), but also on driving aspects such as steering stability, speed adaptation, and anticipating environmental changes. In other words, people with HH need to learn compensatory scanning mechanisms without operational and tactical driving to be affected. The current results provide a wealth of information on the specific driving aspects that deserve attention during training (e.g., perception and judgement during overtaking and passing by appears to be a common and decisive difficulty). Both the visual scanning behavior and the operational handling of the car are found to be poorer, the longer the person has not driven. This emphasizes the need for driving lessons (on-road or in a simulator) to be included in the training program preceding the test of practical fitness to drive.

Acknowledgments

The authors thank all study participants, all colleagues from the Dutch driver's licensing authority involved in the data collection, and all colleagues from Royal Dutch Visio involved in recruitment of participants.

APPENDIX 5.1: TRIP

Position on the Road

1. What is the average lateral positioning on the driving lane (on a regular two-lane road)? *(Too much to the left, approximately in the middle, too much to the right, fluctuating)*

How is the steadiness of steering (swaying and drifting away)?

On Straight Roads

2. speed < 50 km/h
3. speed > 50 km/h

In Curves

4. speed < 50 km/h
5. speed > 50 km/h

When Making Head/Eye Movements

6. speed < 50 km/h
7. speed > 50 km/h

How good is the choice of position for the following specific situations?

8. Lane choice for straight ahead
9. Lane choice for turning right
10. Lane choice for turning left
11. Lane choice for /at roundabouts

Car Following Distance

12. How would you classify the style of car following of the driver? *(short, sufficient, long)*

How well is the following distance adapted to variations of speed of the cars ahead?

13. In town areas
14. Outside town areas

Choice of Speed

15. How would you classify the driver in terms of his choice of speed? *(average, slow, fast)*

How good is the driver's adaptation of speed to the circumstances?

16. In town areas
17. Outside town areas

Observation Behavior (Head and Eye Movements)

General

18. When moving straight ahead
19. Crossing junctions without designated priorities
20. Crossing priority junctions
21. When turning right at junctions or forks
22. When turning left at junctions or forks
23. In curves
24. When using inside mirror
25. When using outside mirror
26. Observation in the blind angle

Anticipatory viewing behavior

27. With regard to changing road situations
28. With regard to changing traffic situations

Traffic Signals (Lights and Signs)

29. Perception
30. Reaction

Overtaking and Passing By

31. Perception and judgement
32. Performing the maneuvers

Anticipation

(At a tactical level, e.g. slowing down when a pedestrian approaches the driving lane)

33. With regard to changing road situations
34. With regard to changing traffic situations

Communication with and Adaptation to Other Traffic Participants

35. With other car drivers
36. With cyclists and pedestrians

Assessment of Specific Situations

A. Turning left on a priority road or no traffic lights.

When Approaching the Junction

37. Adaptation of speed
38. Use of mirrors and looking sideways
39. Operating the direction indicator
40. Position on the driving lane
41. Viewing behavior (head movements)
42. Effectiveness of viewing behavior (seeing other traffic)

At the Junction

43. Choice of position
44. Viewing behavior (head movements)
45. Effectiveness of viewing behavior (seeing other traffic)
46. Application of the priority rules
47. Tempo of perception and action

B. Merging with a fast moving stream of traffic (merging lane trunk road or motorway).

48. Acceleration on the merging lane
49. Looking sideways
50. Adaptation of speed to other traffic
51. Operating the direction indicator
52. Driving on to the main lane

Mechanical Operation

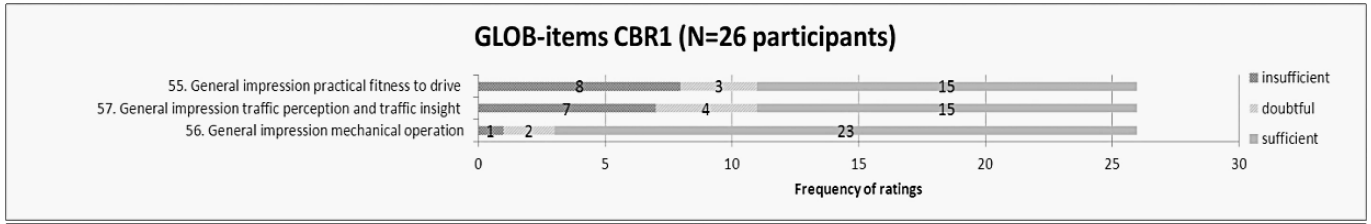
53. Operating the accelerator
54. Operating the brakes

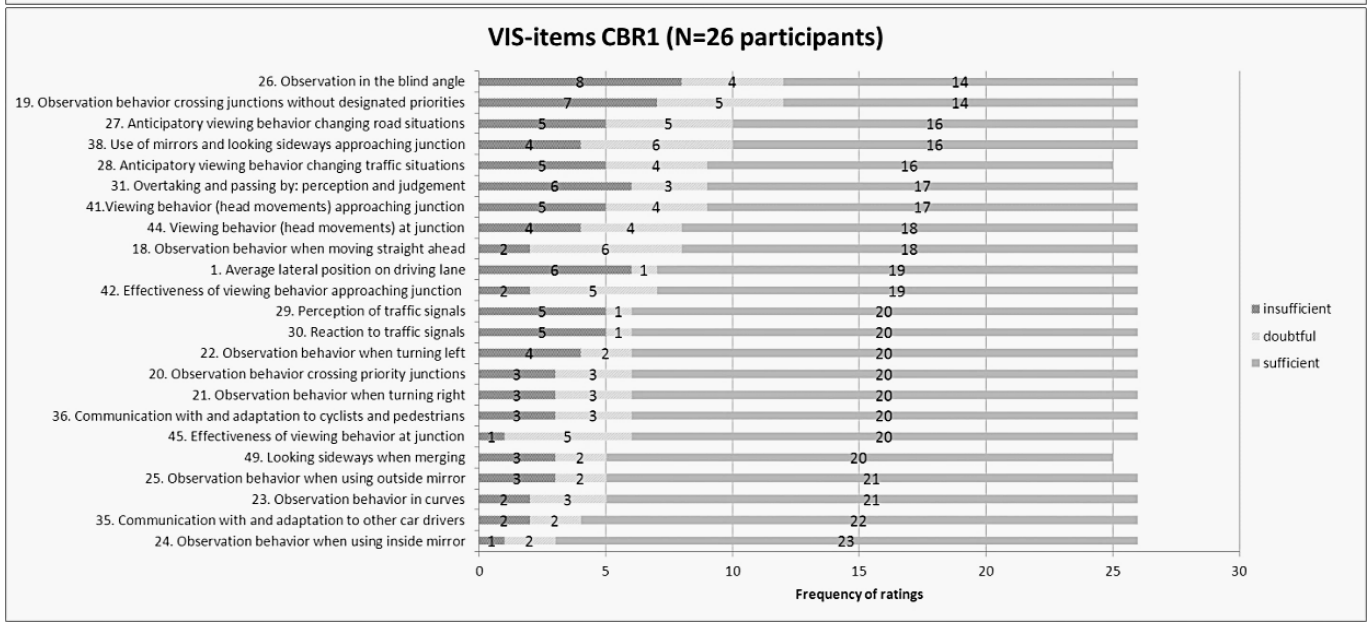
General Impressions

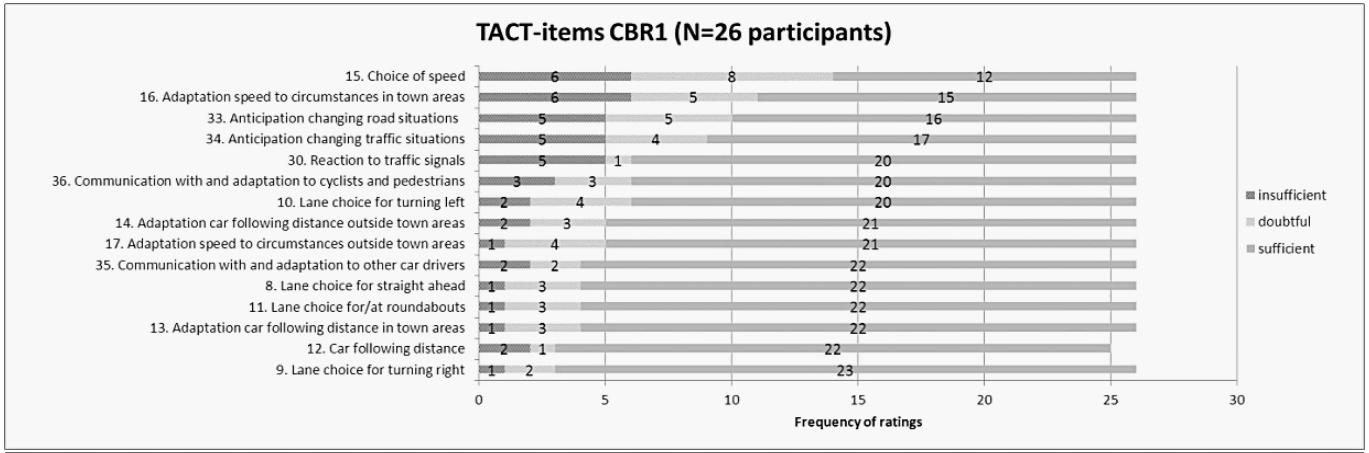
55. Practical fitness to drive (general)
56. Mechanical operation
57. Traffic perception and traffic insight

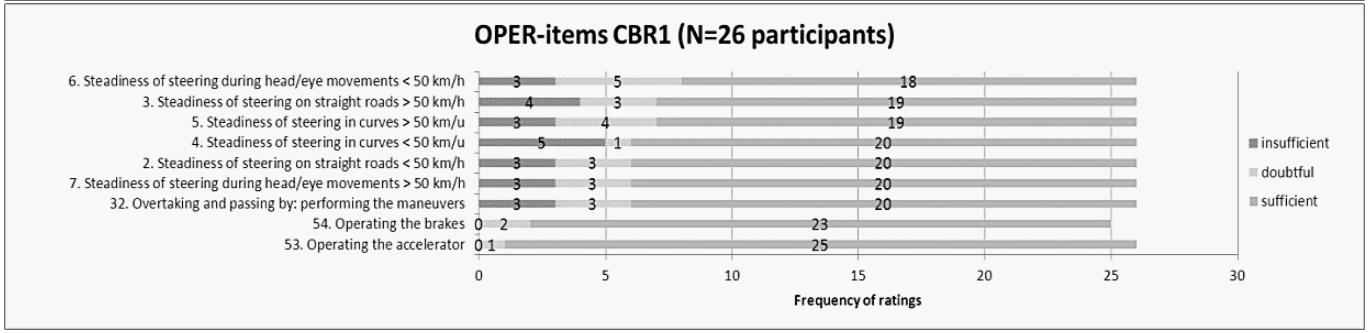
APPENDIX 5.2: RATINGS FOR THE INDIVIDUAL TRIP ITEMS

Frequency of ratings ("sufficient", "doubtful", and "insufficient") for every individual TRIP item, organized by subscale for the total group of participants (*N* = 26). For some items the DPR failed to report a rating, resulting in 25 observations instead of 26.






TACT-items CBR1 (N=26 participants)
15. Choice of speed
16. Adaptation speed to circumstances in town areas
33. Anticipation changing road situations
34. Anticipation changing traffic situations
30. Reaction to traffic signals
36. Communication with and adaptation to cyclists and pedestrians
10. Lane choice for turning left
14. Adaptation car following distance outside town areas
17. Adaptation speed to circumstances outside town areas
35. Communication with and adaptation to other car drivers
8. Lane choice for straight ahead
11. Lane choice for/at roundabouts
13. Adaptation car following distance in town areas
12. Car following distance
9. Lane choice for turning right
6 8 12
6 5 15
5 5 16
5 4 17
5 1 20
3 3 20
2 4 20
2 3 21
1 4 21
2 2 22
1 3 22
1 3 22
1 3 22
2 1 22
1 2 23
0 5 10 15 20 25 30
Frequency of ratings
insufficient
doubtful
sufficient


OPER-items CBR1 (N=26 participants)
6. Steadiness of steering during head/eye movements < 50 km/h
3. Steadiness of steering on straight roads > 50 km/h
5. Steadiness of steering in curves > 50 km/u
4. Steadiness of steering in curves < 50 km/u
2. Steadiness of steering on straight roads < 50 km/h
7. Steadiness of steering during head/eye movements > 50 km/h
32. Overtaking and passing by: performing the maneuvers
54. Operating the brakes
53. Operating the accelerator
3 5 18
4 3 19
3 4 19
5 1 20
3 3 20
3 3 20
3 3 20
0 2 23
0 1 25
0 5 10 15 20 25 30
Frequency of ratings
insufficient
doubtful
sufficient

APPENDIX 5.3: ERRATUM VALUES CONTRAST SENSITIVITY

After publishing the original paper, we discovered that an older version of the GECKO chart was used in the study. However, we had used the values for peak contrast sensitivity corresponding to the new GECKO chart. Therefore, the correct values slightly deviate from the published values. A notification has been sent to the journal that published the original paper.

Erratum Table 5.1. Participant Characteristics.

	Fit to drive (*n* = 14)	Unfit to drive (*n* = 12)	Total (*N* = 26)
contrast sensitivity: as presented in Table 1 of original paper	2.07 (0.23)	2.15 (0.05)	2.11 (0.18)
contrast sensitivity: correct values	1.93 (0.16)	1.99 (0.04)	1.96 (0.13)

Note: The change in values does not lead to a change in the results of the analyses regarding contrast sensitivity. In both cases, no significant difference was found between the fit and unfit drivers regarding contrast sensitivity.

6

The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: a randomized controlled trial

De Haan, G. A., Melis-Dankers, B. J., Brouwer, W. H., Tucha, O., & Heutink, J. (2015). The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: a randomized controlled trial. *PloS One, 10*(8), e0134459.

ABSTRACT

Introduction: Homonymous visual field defects (HVFD) are a common consequence of postchiasmatic acquired brain injury and often lead to mobility-related difficulties. Different types of compensatory scanning training have been developed, aimed at decreasing consequences of the HVFD by changing visual scanning.

Aim: The aim of the present study is to examine the effects of a compensatory scanning training program using horizontal scanning on mobility-related activities and participation in daily life.

Method: The main interest of this study is to assess the effectiveness of training on mobility-related activities and participation in daily life. Visual scanning tests, such as dot counting and visual search, and control measures for visual functions and reading have been included as well. First, it is examined how performance on scanning and mobility-related measures is affected in patients with HVFD by comparing scores with scores of a healthy control group (n = 25). Second, the effect of training is assessed using an RCT design, in which performance of 26 patients before and after training is compared to performance of 23 patients in a waiting list control group.

Results: Self-reported improvements after training were found, accompanied by improvements in detecting peripheral stimuli and avoiding obstacles during walking, especially in dual task situations in which a second task limits the attentional capacity available for compensatory scanning. Training only improved mobility-related activities in which detection of peripheral stimuli is important, while no improvement was found on tests that require other visual skills, such as reading, visual counting and visual search.

Conclusion: This is the first RCT to evaluate the effects of a compensatory scanning training that is based on a systematic horizontal scanning rhythm. This training improved mobility-related activities. The results suggest that different types of compensatory scanning strategies are appropriate for different types of activities.

INTRODUCTION

Homonymous visual field defects (HFVDs) are a common consequence of acquired brain damage and refer to visual field defects similar for both eyes and contralateral to the brain damage. The most common form of a HVFD is homonymous hemianopia, in which the left or the right half of the visual field is not perceived. Homonymous hemianopia is estimated to occur in 8-31% of all stroke patients (Feigenson et al., 1977; Gilhotra et al., 2002), but can also be caused by traumatic brain injury, brain tumor, or other pathologies (e.g. multiple sclerosis, epileptic disorders, MELAS, and the posterior form of Alzheimer disease) (Trobe et al., 1973; Zhang et al., 2006a).

After one month, spontaneous recovery of the visual field, at least partly, is seen in 50% to 69% of patients with hemianopia (Ali et al., 2013; Pambakian & Kennard, 1997; Zhang et al., 2006b). Most patients become aware that they should compensate by looking towards the blind side. However, spontaneous recovery and spontaneous compensation are often insufficient so that considerable difficulties with activities in daily life and independent living remain (De Haan, Heutink, Melis-Dankers, Brouwer, & Tucha, 2015, chapter 4). Patients with HVFDs often report difficulty in scanning their surroundings fast enough to detect all objects

and people in time, leading to feelings of insecurity and difficulty with orientation and mobility (Kerkhoff, Munssinger, Haaf et al., 1992). This is illustrated by the finding that in a group of patients with HVFD referred for low-vision rehabilitation, almost 90% indicated they frequently collide with people or objects on the side of the HVFD (Warren, 2009). These mobility problems often restrict participation in society considerably and may lead to marked impairments of quality of life (De Haan, Heutink et al., 2015; Gall, Franke et al., 2010; Papageorgiou et al., 2007; Wagenbreth et al., 2010).

Compensatory scanning training (CST) aims to decrease the impact of the visual field defect by enlarging the functional field of view through optimizing visual scanning. Based on different rationales, several CST programs have been developed. Most programs include computerized exercises to stimulate compensatory scanning and these exercises can be divided in three categories. The first type of exercise is based on visual search in which patients have to find one or more targets among distractors (Aimola et al., 2014; Kerkhoff, Munssinger, Haaf et al., 1992; Kerkhoff et al., 1994; Lane et al., 2010; Mannan et al., 2010; Moedden et al., 2012; Pambakian et al., 2004; Roth et al., 2009; Schuett et al., 2012; Zihl, 1995b). Exercises of the second type focus on finding a target not surrounded by distractors, with the target appearing at unpredictable positions (Blythe et al., 1987; Bolognini et al., 2005; Hayes, Chen, Clarke, & Thompson, 2012; I. Keller & Lefin-Rank, 2010; Nelles et al., 2001; Nelles et al., 2009; Nelles et al., 2010; Passamonti et al., 2009). In the third type of exercise participants make fast and large saccades towards targets presented on the horizontal axis specifically (Kerkhoff, Munssinger, Haaf et al., 1992; Kerkhoff et al., 1994; Tant, 2002; Zihl & Von Cramon, 1985; Zihl, 1995b). Some CST programs combine these different types of exercises or apply additional exercises, such as copying complex drawings. Only a few CST programs include exercises to practice transfer of the adapted scanning behavior to activities of daily life (Hayes et al., 2012; Kerkhoff, Munssinger, Haaf et al., 1992; Kerkhoff et al., 1994; Moedden et al., 2012; Nelles et al., 2009; Nelles et al., 2010; Tant, 2002).

Previous studies on the effect of CST have been encouraging, but the impact on activities of daily living is unclear (Bouwmeester et al., 2007; De Haan et al., 2014; Kerkhoff, 1999; Pollock et al., 2011). In many studies part of the tests used to assess the effect of training tended to be very similar to the exercises practiced during training (Aimola et al., 2014; Blythe et al., 1987; Bolognini et al., 2005; Kerkhoff, Munssinger, Haaf et al., 1992; Kerkhoff et al., 1994; Lane et al., 2010; Mannan et al., 2010; Nelles et al., 2001; Pambakian et al., 2004; Roth et al., 2009; Schuett et al., 2012; Tant, 2002). Very few studies incorporated mobility-related tests (Aimola et al., 2014; Hayes et al., 2012; Tant, 2002). Only little evidence has been found for transfer of CST effects to activities of daily life beyond the specific tasks that were trained. Furthermore, the majority of these studies used within-subjects designs. A small number of the effect studies on training with visual search exercises used a randomized controlled trial (RCT) design to compare the effects of CST with a control group (Aimola et al., 2014; Lane et al., 2010; Moedden et al., 2012; Roth et al., 2009; Schuett et al., 2012), but no RCTs have been performed for training with a focus on horizontal scanning strategies. In conclusion, a well-designed study on the effects of CST on mobility-related activities and participation is needed.

The aim of the present study is to examine the effects of a CST program on an extensive set of scanning and mobility-related measures. This CST teaches patients with HVFDs a systematic

scanning rhythm using exercises of horizontal scanning. The main interest of this study was to examine the effects of training on mobility-related activities and participation. Visual scanning tests, such as dot counting and visual search, were included as well, in order to examine various underlying visual performance and in order to enable comparison with the previous studies on the effects of CST. Furthermore, control measures for visual functions and reading have been included. It was hypothesized that this CST would improve scanning and mobility related activities, while visual functions, such as visual field size, would not be affected by the intervention. No effect on reading was expected, since two previous studies found no effect of CST on reading performance (Lane et al., 2010; Roth et al., 2009). While reading relies on small saccades, this training focusses on large horizontal saccades. First, it is examined how performance on scanning and mobility-related measures is affected in patients with HVFD by comparing these patients with a healthy control group. Second, the effect of training is assessed using an RCT design, in which performance of patients before and after training is compared to performance of patients in a waiting list control group.

MATERIALS AND METHODS

Ethics

The protocol for this trial and supporting CONSORT checklist are available as supporting information; see S1 Checklist and S1 Protocol (available at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134459). The study protocol was approved by the Medical Research Ethics Committee of the University Medical Center Groningen (registration number METc 2010/078) and by the relevant patient organizations. This study was registered at the Central Committee on Research Involving Human Subjects (CCMO; www.ccmo.nl/en; registration number NL31718.042.10). The study was registered as a clinical trial at the ISRCTN Registry [ID ISRCTN16833414; URL http://www.isrctn.com/ISRCTN16833414]; Registration occurred after the trial began since the research group was not aware that this study design required public registration as a clinical trial. The authors confirm that all ongoing and related trials for this intervention are registered. The study was performed in accordance with the 2008 Declaration of Helsinki. All participants gave their informed written consent. For all participants, there was no reason to doubt their capacity to consent, since they all had the capacity to sign the rehabilitation contract themselves and to formulate their individual goals for rehabilitation during the registration stage at the rehabilitation center, and they all had MMSE scores ≥ 24 out of 30.

Design

Patients with HVFD were assigned to either the training group or the waiting list control group. The flow chart of the study is presented in Figure 6.1. Patients in the training group were assessed the week before training (T1) and the week after training (T2). Patients in the waiting list control group also participated in two assessments, but received no training in between. Time between assessments was 13 weeks for both groups. This was 16 weeks for one included patient of the training group, because he cancelled T2 because of other private and work-related engagements, and a new appointment could be made for three weeks later (there was no breach of training, no further training after 13 weeks and his scores were not outliers). The

CONSORT
TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram

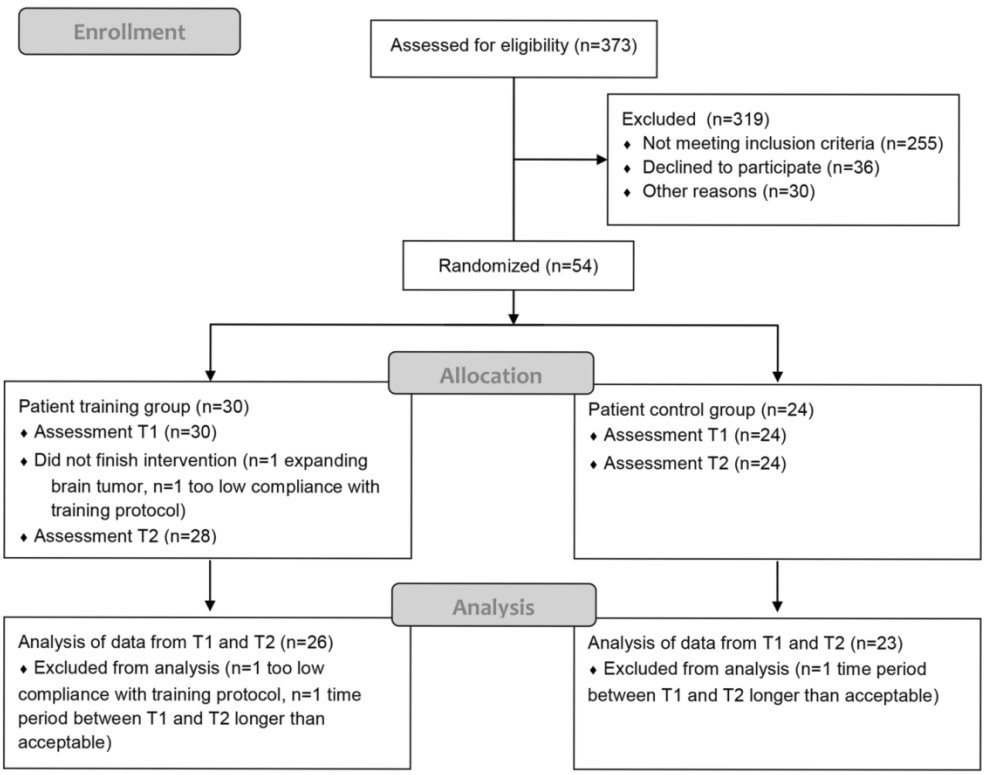


Figure 6.1. Consort statement flow chart.

assessments and training took place between March 2010 and October 2012. For patients in the training group, training could be extended with a number of sessions after T2 outside the scope of this study, dependent on the mobility goals set out at the start of the training. Patients in the waiting list control group were offered training after T2.

Allocation to the groups occurred by the method of minimization (Pocock & Simon, 1975). This is a dynamic procedure that calculates for a new participant the difference for each of a set of predefined, dichotomous factors, based on the characteristics of the participants already included in the two groups. The method of minimization is demonstrated to be superior to complete randomization for the sample size in our study (Matthews, Cook, Terada, & Aloia, 2010). Differences between the groups were minimized regarding gender, side of field defect

(left or right), size of field defect (hemianopia vs. quadrantanopia), age (younger vs. older than 55), and time since onset (shorter vs. longer than 12 months). Because time since onset was assumed less important than the other variables, this variable was weighted less heavily (0.5) than the others (1.0). Upon inclusion of a new participant, author GH entered the characteristics of the patient into the randomization software that contained the characteristics of the previously included patients, which resulted in allocation to the training group or the waiting list control group.

For the healthy control group, the scanning and mobility-related tests were administered at T1 only. Assessments of the healthy control participants took place between October and December 2012.

Performance of the two patient groups at T1 are compared to performance of the healthy control group and changes between T1 and T2 in the training group are compared to changes in the waiting list control group.

Sample size

The sample size was based on previous studies on the effect of CST (in terms of reaction times, eye movement parameters, data from ADL tasks and questionnaire data) (Pambakian et al., 2004; Zihl, 1995b). Taking the lowest value encountered (effect size = 0.65), a minimum of 30 participants per group would be required (training group vs. waiting list control group; two independent groups; $\alpha = 0.05$; $\beta = 0.20$; one-sided testing). When comparing pre and post assessments within a group of 60 participants, effect sizes of 0.34 can be detected with power 0.80 and one-sided testing with .05 significance. This means that even in case of low effectiveness of compensatory scanning training, a group size of $n = 60$ would be fully sufficient. Therefore, the aim was to recruit 30 participants for each patient group.

Participant recruitment

Patients were recruited at Royal Dutch Visio and Bartiméus, the two centers of expertise for blind and partially sighted people in the Netherlands. The main inclusion criterion was presence of a HVFD, at least a quadrantanopia, restricted to one half of the visual field, due to acquired postchiasmatic brain injury. Visual field defects that covered the major parts of two quadrants were regarded as hemianopia, while smaller field defects were classified as quadrantanopia. In order to minimize the chance of spontaneous visual field recovery, time since onset had to exceed 5 months, minimizing chances for spontaneous recovery of the field defect. Between January 2010 and July 2012, 373 patients suspected of having such an HVFD were registered. In order to examine the inclusion criteria, patients underwent extensive and standardized ophthalmological and neuropsychological assessments at the centers mentioned above prior to participation in the study. The following tests were included in the neuropsychological assessments: Mini Mental State Examination, Eight word test, Hospital Anxiety and Depression Scale, Trail Making Test, Visual Object and Space Perception, Balloons, Drawings, Line Bisection, Rey Complex Figure Test, and behavioral tests for optic ataxia and sticky fixation. To be included, patients required a minimum binocular visual acuity of Snellen 0.5 (6/12 or 20/40, LogMAR 0.3), a stable neurological and ophthalmological condition, non-disturbed eye and head motility, ability to walk at least 50 meters, and a MMSE score ≥ 24 out

of 30. Exclusion criteria were ocular diseases affecting the visual field or binocular visual acuity, signs of severe physical impairments or (neuro)psychological disorders. Neglect was excluded based on the Balloons, drawings, Line Bisection and Rey Complex Figure Test.

Besides patients with HVFD, healthy control participants without visual disorders and without brain damage were recruited. They were only included in the study when they were confirmed not to have physical, neurological or psychological impairments that constrain mobility. Binocular visual acuity had to exceed Snellen 0.8 (6/7.5 or 20/25, LogMAR 0.1) and MMSE scores of at least 24 out of 30 were required. The healthy control group was matched with the patient group regarding age and level of education. Recruitment of healthy control participants took place in October and November 2012.

Training

The Template for Intervention Description and Replication checklist is available as supporting information; see S2 Checklist (available at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134459). The training protocol was developed at Royal Dutch Visio and abbreviated as IH-CST (InSight-Hemianopia Compensatory Scanning Training). Training according to this protocol was provided in Dutch at nine locations of Royal Dutch Visio and one location of Bartiméus in the Netherlands. Training was given by occupational therapists that followed complementary theoretical and practical in-service education on the IH-CST protocol. They were extensively supervised by two therapists with years of experience with the training paradigm. The training consisted of 15 individual sessions of 60-90 minutes each, 18.5 hours of face-to-face training in total during a period of 10 weeks. The aim of the IH-CST is to teach patients with HVFD to apply a systematic, anticipatory scanning strategy in order to compensate for their visual field defect during a wide range of mobility-related activities. Similar to the training described by Tant (2002), patients are taught a scanning strategy consisting of a triad of horizontal saccades. In the IH-CST, the scanning strategy is to start with one large saccade towards the blind side, followed by a large saccade ending on the peri-central seeing side, and then back to the starting point of looking straight forward. The large saccade from the center towards the blind side is 44 degrees of visual angle at maximum. This is the largest saccade most people can make without moving the head. Patients learn to generate this scanning rhythm endogenously on an anticipatory basis and to adjust the speed of repetition of this scanning rhythm to environmental demands and to the speed of walking, cycling, etc. The underlying idea is that early detection of obstacles is of high importance during mobility. When an obstacle is detected, one can anticipate to the situation in order to avoid collision with the obstacle. For patients with HVFD, the reduced visual input makes it challenging to create and sustain a proper visual overview. In order to compensate for the loss of visual information caused by the visual field defect, frequent application of large saccades towards the blind side is needed.

Figure 6.2 illustrates different elements of the IH-CST. The protocol starts with exercises for improving awareness of the size and shape of the visual field defect and its consequences for daily life activities. Then, the scanning rhythm is systematically practiced with several exercises gradually increasing speed and amplitude of the scanning triad. At first, only eye movements are allowed, since eye movements are faster than head movements, they do not lead to neck-

muscle complaints and they naturally precede head movements. In a later stage, head movements following the eye movements are practiced to increase the range of scanning. A substantial part of the training is dedicated to the practicing of the scanning rhythm in a range of daily life mobility situations, with increasing complexity and cognitive load, in order to optimize transfer to visual activities and participation in daily life. For every exercise, specific targets are defined for speed and amplitude of the scanning rhythm as well as transfer to an activity of daily life, which must be reached before the participant proceeds to the next exercise. For example, practicing the scanning rhythm during cycling will only be started after scanning during walking is performed without problems. Depending on the needs of the patient, some other compensatory techniques are practiced, for example searching for an object on a shelf. The main reason for including these exercises is that they are expected to increase insight into the field defect. The focus of the IH-CST, however, is on applying a systematic, anticipatory scanning rhythm during a wide range of mobility-related activities.

Homework assignments

In order to stimulate transfer to daily life, homework assignments are included in the training protocol. The first homework assignment is aimed at improving insight in the visual field defect. In this assignment, the patient has to answer a number of questions on what they see and cannot see when looking straight forward in a number of predefined situations.

Further homework assignments are aimed at practicing the scanning rhythm in daily life situations, stimulating transfer to daily life. Homework starts with practicing the scanning rhythm using pieces of paper (Figure 6.2C) three times a day for five minutes. First a smaller band is used and then a wider band, in order to increase the amplitude of the saccades.

When the patient is able to perform the scanning rhythm in the right way, the patient is encouraged to practice the scanning rhythm every day while moving around in different situations (no equipment used). The mobility situations build up from quiet, structured and familiar surroundings to busier and more complex and unfamiliar surroundings, depending on the progress the patient has made in applying the scanning rhythm. The homework instructions of the therapist are fitted for the individual patient, depending on the specific goals that were set by the patient at onset of the training. If these goals include cycling for example, then the homework assignments will also include practicing the scanning rhythm while cycling, again from practice in quiet surroundings to more complex surroundings.

Patients are asked to keep a diary of their practice at home and the therapist asks about the progress of the homework assignment at the beginning of every training session. These structured homework assignments are on the one hand aimed at encouraging practice in daily life, but on the other hand prevent the patient from practicing too difficult situations at an early stage of training. The ultimate goal of the training is that use of the scanning rhythm becomes an automated activity, naturally embedded in every mobility situation encountered in daily living.

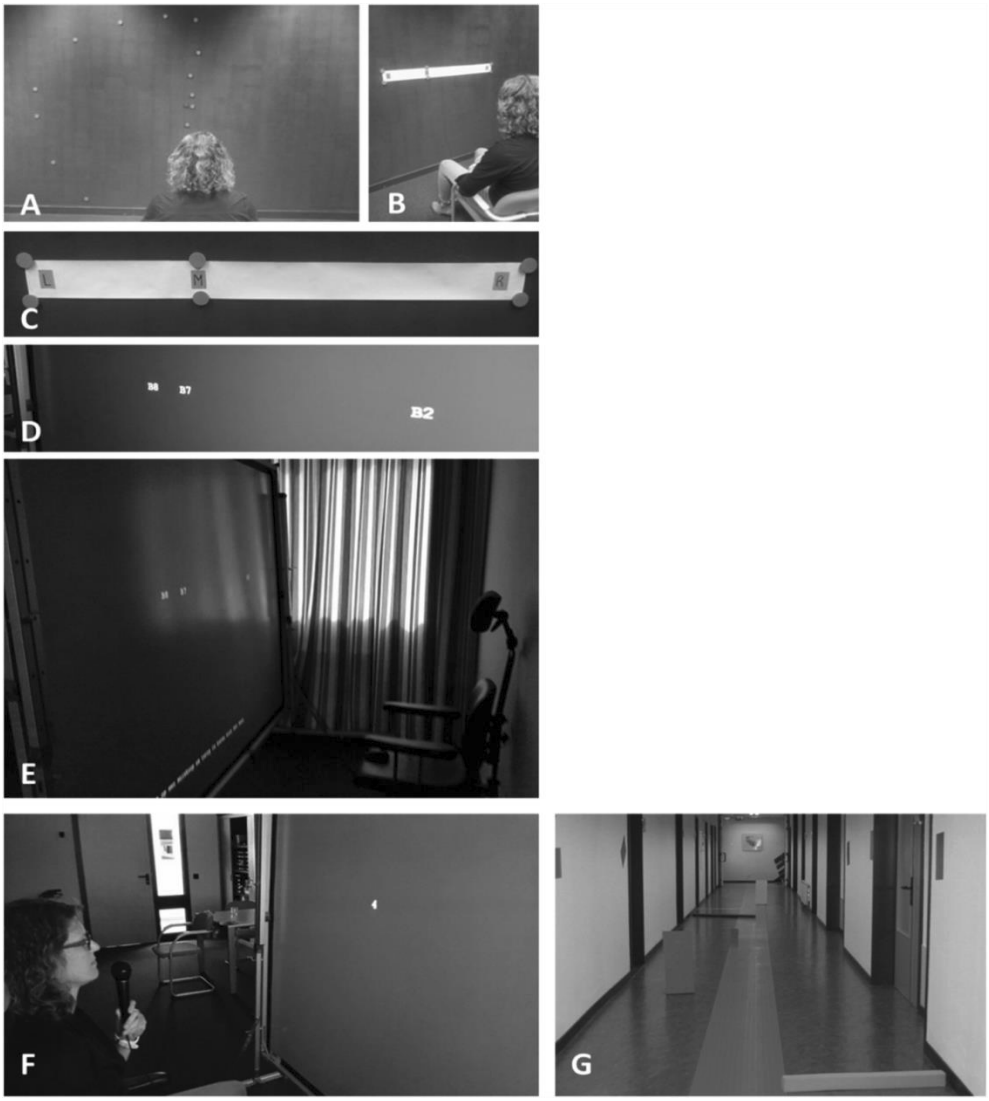


Figure 6.2. Pictures illustrating different elements of the IH-CST, example for right-sided hemianopia. (A) Example of exercises aimed at improving awareness of the size and shape of the visual field defect. The patient is asked to focus at a target in front and indicate the borders of the visual field. Accordingly, the visual field is plotted on the wall with stickers or magnets. (B) Pieces of paper with letters M (middle), R (right) and L (left) used to practice the scanning rhythm. First the paper is laying on a table, then it is attached to a wall in front of the patient (C). The same scanning triad is then presented on a large screen (D). The patient sits in front of this screen in a chair with a head rest (E). Numbers are presented one by one in the order of the scanning triad. The patient has to read the numbers out loud and a microphone is used to record responses (F). After each exercise, the reaction times for targets left, middle and right are presented on the screen. The scanning rhythm is systematically practiced with several exercises gradually increasing speed and amplitude of the scanning triad. (G) A corridor filled with obstacles to practice use of the scanning rhythm during walking. This will be succeeded by practice in a range of daily life mobility situations, with increasing complexity and cognitive load, such as walking in busy shopping areas.

Assessments

Procedure

The assessments were performed by the department of Clinical and Developmental Neuropsychology of the University of Groningen and took place in the University Medical Center Groningen, the Netherlands. Participants were tested individually by assessors who were blinded to participants' group allocation. Communication language during the assessment was Dutch. The results were anonymized and had no influence on training and rehabilitation at the rehabilitation center; no feedback on the results from the assessments was provided to Royal Dutch Visio or Bartiméus for individual patients. In order to increase insight in the degree of difficulty caused by the HVFD, the tests related to scanning and mobility were administered in a healthy control group as well, using the same setup and instructions as for the patient groups.

Tests for visual functions

Monocular visual acuity was tested using the ETDRS 2000 Letter Chart at 4 meters and 500 lux (Ferris, Kassoff, Bresnick, & Bailey, 1982). Contrast sensitivity was measured using the Gecko Test at 3 meters and 500 lux (Kooijman, Stellingwerf, Van Schoot, Cornelissen, & Van der Wildt, 1994). Monocular visual fields were plotted with Goldmann perimetry (isopters V-4, III-4 and I-4) while continuously checking stability of fixation. An independent orthoptist experienced with interpreting perimetry plots of HVFD patients, further analyzed perimetry output. Plots were recoded so that the orthoptist was unaware at which assessment the plot was made. Functional Field Score (FFS) (American Medical Association, 2008; Langelaan, Wouters, Moll, Boer, & Rens, 2005) was calculated from the plots of isopter III-4 using the overlay grid from Langelaan (Langelaan et al., 2005), in which the center and lower half of the visual field weigh more heavily since they are deemed functionally more important. To check whether visual fields changed between T1 and T2, it was evaluated for every participant and each eye whether the border between the blind and intact part of the visual field had shifted at least 5°. For the healthy control group, it was only checked whether visual acuity exceeded Snellen 0.8 (6/7.5 or 20/25, LogMAR 0.1) and no other assessments were performed regarding visual functions.

Reading tests

Two different reading tests were administered. The Radner reading chart (Maaijwee, Meulendijks, Radner, Van Meurs, & Hoyng, 2007; Radner et al., 1998) consists of sentences with decreasing text size that have to be read out loud. Viewing distance was 40 cm. Outcome measures were average reading speed in sentences 3-7, as these sentences could be read by all participants, and minimal readable text size expressed in LogRad units. In a second reading test, participants read out loud a text of approximately 400 words. Participants were allowed to choose their preferred viewing distance while reading the text. After reading the text, participants answered two questions about its content. Reading speed and correct answers were measured. For both tests, preferred glasses or lenses were allowed. Three parallel versions of both reading tests were used in a Latin Square design (on T1 and T2 respectively, subject 1 completed versions 1 and 2, subject 2 completed versions 2 and 3, subject 3 completed versions 3 and 1, etc.).

Figure 6.3. Examples of displays from the dot counting test, parallel search test and serial search test.

Basic scanning tests

Three basic scanning tests were administered (Figure 6.3). In the first test, participants counted dots in 32 different dot patterns. Half of the trials contained few dots (6, 7, 8 or 9 dots, 4 trials each); the other half contained many dots (18, 19, 20 or 21 dots, 4 trials each). Order of trials was randomized once and the same order was applied to all participants at all assessments. The second test was a visual search test in which participants indicated whether or not the letter O was present among T's (parallel search), while in the third test presence of the letter G among C's was questioned (serial search). Stimuli were presented on a large screen (40° horizontally and 33° vertically) with a viewing distance of 192 cm. Participants were allowed to move their head while scanning. No instructions on how to scan the images were given. Reaction times as well as accuracy scores were recorded. For the dot counting test, reaction times and proportion of correct responses were also calculated for trials with few dots and trials with many dots separately. For the visual search tests, reaction times were analyzed by target trials and non-target trials as well. Besides the total number of errors, i.e. omission errors plus commission errors, the number of omission errors was analyzed separately.

Hazard perception test

The hazard perception test is described in more detail by Vlakveld (2011). Twenty-five photos of traffic situations were presented from the view point of a car driver. After looking at each photo for eight seconds, participants choose whether in the given situation they would brake, release the accelerator or keep the same speed (i.e. no intervention). In the current study, size of the photos was 40° by 25° and viewing distance was 192 cm. Head movements were allowed and no instructions on scanning strategies were provided. Besides the number of incorrect responses (absolute error rate), the adapted error rate and risk-index were calculated. The adapted error rate was calculated by the amount of incorrect responses, with very risky responses ("no intervention" when the correct response is "braking") and very cautious responses ('braking" when the correct response is "no intervention") counting as two errors. The risk-index was defined by the proportion of risky answers (risk-index = (2*very risky responses + risky responses) / adapted error rate).

Tracking Task

The Tracking Task is a test of divided attention based on an earlier version described by Brouwer et al. (2002). Participants were seated in front of a simple driving simulator, in which they were driving on a straight road with fixed speed. Participants first practiced use of the

steering wheel for one minute. They were then instructed to maintain a stable position on the middle of the right lane. This required continuous attention because of an imaginary cross-wind influencing the lateral position on the road. During a three-minute cross-wind assessment, maximum cross-wind was determined for which deviation in lateral position was still within predefined limits, followed by a two-minute practice of driving with this amount of cross-wind. Two peripheral screens on which arrows were presented, were positioned on the left and right of the driving simulator. One arrow at a time was presented and the locations (left or right screen) proceeded in a non-predictive order. Participants pressed the button on the steering wheel corresponding to the pointing direction of the arrow (i.e. left or right) as fast and accurate as possible. In case the participants did not respond within 5 seconds, the arrow disappeared and no reaction time was registered. In the single task condition, no steering was required because position on the road was fixed. This condition continued for two minutes, preceded by one minute of practice. During the dual task condition, lane tracking and peripheral detection were combined. This condition lasted for six minutes, preceded by two minutes of practice. The cross-wind strength as individually determined during the cross-wind assessment of T1 was applied in the dual task conditions of both T1 and T2.

Head movements were allowed since these are part of natural scanning behavior. Standard deviation in lateral position on the road (SDLP), as well as omission errors, number of faulty responses and reaction times for the peripheral stimuli were recorded for the dual task condition. The dual-to-single-task-ratio (DSR) was calculated by dividing the mean reaction time in the dual task condition by the mean reaction time in the single task condition.

Obstacle course

The effects of obstacles and cognitive load on walking speed were examined in a standardized obstacle course inside the hospital. Participants were asked to walk through a straight corridor with a comfortable pace, turn around at the end and walk back. Total length (back and forth) of the course was 35 meters. First, the corridor was free of obstacles and preferred walking speed was measured. Then participants walked through the empty corridor while cognitive load was added by asking the participant to repeat verbally presented digit series while walking. Length of the digit series was equal for T1 and T2 and matched the maximum amount of digits the participant was able to repeat correctly as determined beforehand (with the WAIS-Digit Span Forward). Subsequently, participants walked through the corridor filled with 32 obstacles. These were obstacles that could be encountered in real life, such as chairs and litter bins. The obstacles were positioned in a standardized way and participants had to sway through the course in order to avoid touching the obstacles. The obstacles course was first walked with and then without the cognitive dual task.

Contact with obstacles and proportion correct answers on the digit series (Digit Score) were analyzed for the condition with obstacles and with cognitive load. The percentage preferred walking speed (PPWS) was calculated by dividing the walking speed in the obstacle course with cognitive load by the walking speed in the obstacle free corridor with cognitive load.

Questionnaires

Three standardized questionnaires were applied to assess the impact of the HVFD on activities and participation in daily life. In the Visual Functioning Questionnaire (NEI-VFQ-25) (Mangione et al., 2001; Van der Sterre et al., 2001), participants rate the impact of their visual impairment on several health-related domains, such as emotional well-being, social functioning and a number of activities. The Independent Mobility Questionnaire (IMQ) (Turano et al., 1999) assesses the level of difficulty the participant experiences because of visual impairment in a wide range of mobility-related situations. The Cerebral Visual Disorders questionnaire (CVD) consists of two parts. The first part was originally developed by Kerkhoff and colleagues (1990) and asks the participant whether nine vision-related problems were experienced or not. The second part consists of questions about the level of difficulty experienced in twelve specific activities (Dittrich, 1996, as cited in Tant, 2002, p.75). The questionnaires were administered during a structured interview, i.e. orally, since reading difficulties are common in patients with HVFD. The three total scores of the questionnaires yielded the main outcome measures. For the NEI-VFQ-25, higher scores indicate less difficulty experienced by the patient, while for the IMQ and CVD, higher scores refer to more difficulty.

Statistical analysis

Participant characteristics were compared between the patient training group (P-TRAINING), the patient waiting list control group (P-WAITING) and the healthy control group (HEALTHY) using ANOVA and post-hoc tests (Least Significant Difference) for age and level of education, two-tailed independent samples t-test for FFS and time since onset, and two-tailed Chi-Square Test for gender, etiology and side of HVFD. Test performance in the two patient groups at T1 was compared to test performance of the healthy control group with a two-tailed independent samples t-test. The effect of training was examined by the group*time interaction effects from General Linear Model (GLM) Repeated Measures analysis, with group (P-TRAINING vs. P-WAITING) as the between-subjects factor and time (T1 vs. T2) as the within-subjects factor. In the GLM, FFS at T1 was inserted as a covariate (except for the analyses on visual functions), because FFS at T1 was significantly higher for the waiting list control group than for the training group ($t(38.2) = -2.08$, $p = .045$). Within-group changes between T1 and T2 were examined with two-tailed matched pairs t-test for the training group and waiting group separately. In case of a significant interaction effect in the GLM, the two patient groups were compared using a two-tailed independent samples t-test for T1 and T2 separately. Changes in the border of the visual field defects were analyzed with a Chi-square test, comparing the distributions between the training group and waiting list control group.

There was no evidence for serious violations of the assumptions for all statistical tests. For the two-tailed independent samples t-test, the assumption of equal variances in the two groups was tested with Levene's test for equality of variances. In case equal variances cannot be assumed, the unequal-variance t-test was performed. Cases with missing values (because of measurement flaws, technical bugs or shortage of testing time e.g. in case of late arrival due to rush hour) were excluded pairwise. Significant effects were defined by p-values < .05. In case of a p-value below .10, the exact p-value is reported. Effect sizes belonging to the group*time interactions were calculated with the formula for effect size estimate d_{ppc2} as described by

Morris (2008). Effect sizes for the within-group and between-group comparisons were calculated according to Cohen's *d* (Cohen, 1988). Effect sizes were classified as negligible ($d < 0.20$), small ($d > 0.20$), medium ($d > 0.50$) or large ($d > 0.80$).

RESULTS

The individual-level data are provided in S1 File (available at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134459).

Participants

Fifty-four patients with unilateral HVFD were included and data from 49 patients were analyzed. Forty-eight patients received training at Royal Dutch Visio and one at Bartiméus. According to the procedure of minimization (Pocock & Simon, 1975), 26 patients were allocated to the training group and 23 to the waiting list control group. Twenty-five healthy control participants were included. The healthy control group contained less men than the combined patient groups ($\chi^2(1) = 9.24$, $p = .002$). Participants' characteristics are summarized in Table 6.1. No important harms caused by the training or the assessments were encountered, nor reported by the participants.

Comparisons between healthy control participants and patients at T1

The mean test scores and standard deviations are presented in Table 6.2. The effect sizes of the comparisons are presented in Table 6.3. These tables also include the abbreviations of the parameters as referred to throughout the results section.

Table 6.1. Summary of participant characteristics (mean ± SD, range).

		Training group (*n* = 26)	Waiting list control group (*n* = 23)	Healthy control group (*n* = 25)	*p*-value
Gender	Men	18	14	7	.002 [b] (Chi^2 Test, combined patient group vs. HEALTHY); .539 (Chi^2 Test, P-TRAINING vs. P-WAITING)
	Women	8	9	18	
Age (years)		55 ± 10.1 [27;70]	57 ± 13.0 [29;74]	53 ± 14.5 [28;76]	.639 (ANOVA); .732 (post-hoc P-TRAINING vs. HEALTHY); .351 (post-hoc P-WAITING vs. HEALTHY)
Level of education [a]		5.3 ± 0.8 [4;7]	5.3 ± 1.1 [2;7]	5.5 ± 0.8 [4;7]	.624 (ANOVA); .399 (post-hoc P-TRAINING vs. HEALTHY); .406 (post-hoc P-WAITING vs. HEALTHY)
Etiology	iCVA	18	18		.953 (Chi^2 Test)
	hCVA	3	2		
	TBI	2	1		
	PHT	1	0		
	AVM extirpation	0	1		
	combined	2	1		
Side of HVFD	Left HVFD	18	15		.765 (Chi^2 Test)
	Right HVFD	8	8		
Visual field size	Functional Field Score (FFS)	58 ± 7.8 [48;80]	64 ± 11.4 [48;84]		.045 [b] (t-test)
	Quadrantanopia	5 (3 LL, 1 UL, 1 LR)	5 (3 LL, 2 UL)		
	Hemianopia	21	18		
Time since onset of HVFD (months)		18 ± 22.5 [5;122]	22 ± 24.6 [7;106]		.528 (t-test)

[a] Level of education according to Verhage (Duits & Kessels, 2006); higher values represent higher levels of education.

[b] Significant difference (p-value < .050).

iCVA = ischemic cerebrovascular accident, hCVA = hemorrhagic cerebrovascular accident, TBI = traumatic brain injury, PHT = penetrating head trauma, AVM = arteriovenous malformation, combined = combined etiology.

LL = lower left quadrantanopia, UL = upper left quadrantanopia, LR = lower right quadrantanopia.

Table 6.2. Test scores (mean ± SD).

	Training group			Waiting list control group			Healthy control group	
	n	T1 (Before training)	T2 (After training)	n	T1 (Early pre-assessment)	T2 (Before training)	n	T1
Tests for visual functions								
Visual acuity right eye (VOD)	26	0.90 ± 0.28	0.91 ± 0.29	23	0.90 ± 0.25	**0.99 ± 0.26 b**	-	
Visual acuity left eye (VOS)	26	0.97 ± 0.26	0.97 ± 0.25	23	0.90 ± 0.26	0.92 ± 0.26	-	
Contrast sensitivity*	26	2.08 ± 0.21	2.13 ± 0.12	23	2.07 ± 0.17	2.04 ± 0.27	-	
Functional Field Score (FFS)	26	**57.92 ± 7.80 c**	57.75 ± 6.74	23	63.79 ± 11.41	62.58 ± 11.13	-	
Reading tests								
Radner average reading speed(wpm)	24	153 ± 31	159 ± 33	21	146 ± 41	147 ± 34	-	-
Minimal readable text size (LogRad)	24	0.08 ± 0.15	0.09 ± 0.12	21	0.07 ± 0.10	0.07 ± 0.12	-	-
Text reading speed (wpm)	23	133 ± 23	136 ± 27	21	125 ± 31	135 ± 35	-	-
Text correct answers	24	1.46 ± 0.66	**1.79 ± 0.42 b**	21	1.62 ± 0.59	1.67 ± 0.48	-	-
Basic scanning tests								
Dot counting test								
Reaction times (ms)								
All trials (Dots-RT-all)	21	**8904 ± 3434 a**	8515 ± 3812	23	**9293 ± 5142 a**	8224 ± 3201	25	6631 ± 1496
Few dots (Dots-RT-few)	21	**5272 ± 2315 a**	4834 ± 2012	23	**5115 ± 1923 a**	**4542 ± 1408b**	25	3214 ± 818
Many dots (Dots-RT-many)	21	**12495 ± 4874 a**	12207 ± 6175	23	13471 ± 8993	11942 ± 5376	25	10048 ± 2347
Proportion correct answers								
All trials (Dots-correct-all)	21	**0.72 ± 0.17 a**	0.75 ± 0.18	23	**0.73 ± 0.24 a**	0.70 ± 0.28	25	0.84 ± 0.12
Few dots (Dots-correct-few)	21	0.93 ± 0.09	0.91 ± 0.20	23	0.88 ± 0.22	0.85 ± 0.28	25	0.96 ± 0.07
Many dots (Dots-correct-any)	21	**0.50 ± 0.29 a**	0.59 ± 0.29	23	0.57 ± 0.31	0.56 ± 0.34	25	0.72 ± 0.21
Parallel search test								
Reaction times (ms)								
All trials (Par-RT-all)	21	**2369 ± 785 a**	2224 ± 838	23	**2183 ± 516 a**	2140 ± 545	25	1196 ± 367
Target present (Par-RT-target)	21	**1539 ± 562 a**	1422 ± 425	23	**1498 ± 425 a**	1416 ± 389	25	996 ± 260
Target absent (Par-RT-notarget)	21	**3199 ± 1027 a**	3027 ± 1286	23	**2868 ± 768 a**	2861 ± 793	25	1396 ± 504
Accuracy								
Total number of errors (Par-err)	20	0.45 ± 0.83	0.40 ± 0.50	23	1.35 ± 2.27	0.83 ± 1.56	25	0.48 ± 0.77
Number of omissions (Par-omis)	20	0.20 ± 0.41	0.25 ± 0.44	23	1.09 ± 2.04	0.70 ± 1.55	25	0.32 ± 0.63

	Training group			Waiting list control group			Healthy control group	
	n	T1 (Before training)	T2 (After training)	n	T1 (Early pre-assessment)	T2 (Before training)	n	T1
Serial search test								
Reaction times (ms)								
All trials (Ser-RT-all)	21	**5563 ± 1592 a**	5258 ± 1541	23	**4998 ± 2039 a**	5196 ± 2269	25	3498 ± 1337
Target present (Ser-RT-target)	21	**3855 ± 1472 a**	3607 ± 1031	23	**3602 ± 1709 a**	3676 ± 1725	25	2600 ± 1321
Target absent (Ser-RT-notarget)	21	**7270 ± 1891 a**	6909 ± 2244	23	**6394 ± 2607 a**	6715 ± 3123	25	4395 ± 1474
Accuracy								
Total number of errors (Ser-err)	21	1.14 ± 1.59	1.57 ± 1.94	23	1.78 ± 2.32	1.78 ± 1.93	25	0.84 ± 1.38
Number of omissions (Ser-omis)	21	0.95 ± 1.12	1.48 ± 1.81	23	1.61 ± 2.04	1.74 ± 1.94	25	0.76 ± 1.39
Hazard perception test								
Absolute error rate	17	**10.41 ± 2.43 a**	9.24 ± 2.33	22	9.32 ± 2.77	8.68 ± 3.00	24	8.50 ± 2.21
Adapted error rate	17	**11.65 ± 3.16 a**	10.12 ± 2.69	22	10.27 ± 3.34	9.55 ± 3.35	24	9.21 ± 2.89
Risk-index	17	0.73 ± 0.16	0.74 ± 0.13	22	0.69 ± 0.21	0.74 ± 0.20	24	0.76 ± 0.18
Tracking Task								
Dual task condition								
Reaction times (ms)								
All stimuli (TT-RT-all)	23	**1200 ± 195 a**	**1109 ± 155 b**	21	**1293 ± 286 a**	1271 ± 341	25	943 ± 147
Stimuli blind side (TT-RT-blind)	23	1487 ± 267	1345 ± 239	21	1539 ± 451	1605 ± 679	-	-
Stimuli seeing side (TT-RT-seeing)	23	**1014 ± 146 c**	982 ± 165	21	1155 ± 271	**1093 ± 248 b**	-	-
Stimuli blind side-stimuli seeing side	23	473 ± 263	362 ± 246	21	384 ± 313	**512 ± 514 e**	-	-
Accuracy								
Number of faulty responses (TT-err)	24	0.67 ± 0.92	0.92 ± 1.02	21	1.19 ± 1.12	0.76 ± 1.14	25	0.84 ± 1.07
Number of omissions (TT-omis)	24	0.29 ± 1.00	0.08 ± 0.28	21	0.38 ± 1.12	0.57 ± 1.54	25	0.04 ± 0.20
Standard Deviation of Lateral Position (SDLP)	23	48.09 ± 9.94	50.30 ± 10.27	21	50.19 ± 10.55	47.31 ± 10.59	25	46.14 ± 6.50
Mean reaction time dual task divided by mean reaction time single task (dual-to-single-task-ratio, DSR)								
All stimuli (DSR-all)	23	**1.27 ± 0.22 a**	**1.10 ± 0.19 b**	20	**1.17 ± 0.20 a**	**1.23 ± 0.22 e**	25	1.00 ± 0.11
Stimuli blind side (DSR-blind)	23	**1.54 ± 0.43 c**	**1.29 ± 0.38 b**	20	1.29 ± 0.31	**1.53 ± 0.63 e**	-	-
Stimuli seeing side (DSR-seeing)	23	1.07 ± 0.20	1.06 ± 0.19	20	1.07 ± 0.22	1.06 ± 0.18	-	-

	Training group			Waiting list control group			Healthy control group	
	n	T1 (Before training)	T2 (After training)	n	T1 (Early pre-assessment)	T2 (Before training)	n	T1
Obstacle course								
Digit Score	24	**0.60 ± 0.31 a**	0.66 ± 0.31	23	0.70 ± 0.27	0.65 ± 0.29	25	0.79 ± 0.24
Number of contacts	24	**2.00 ± 1.98 a**	**0.88 ± 0.90 bd**	23	**2.52 ± 2.59 a**	1.74 ± 1.60	25	0.48 ± 0.65
PPWS	24	**46.36 ± 9.75 a**	**49.68 ± 8.35 b**	23	**48.33 ± 8.67 a**	49.72 ± 11.02	25	57.98 ± 7.88
Questionnaires								
NEI-VFQ-25 total score	26	66.30 ± 12.56	**71.98 ± 10.07 bd**	23	64.10 ± 14.30	**62.39 ± 15.06 e**	-	-
IMQ total score	26	2.48 ± 0.70	**2.04 ± 0.56 bd**	23	2.57 ± 0.68	**2.51 ± 0.72 e**	-	-
CVD total score	26	0.44 ± 0.16	**0.36 ± 0.13 bd**	23	0.45 ± 0.15	**0.46 ± 0.16 e**	-	-

(a) significant difference between the patient group and healthy control group at T1 (independent samples t-test, two-sided p-value < .05).

(b) significant within-group difference between T1 and T2 (matched pairs t-test, two-sided p-value < .05).

(c) significant difference between training group and waiting list control group at T1 (independent samples t-test, two-sided p-value < .05).

(d) significant difference between training group and waiting list control group at T2 (independent samples t-test, two-sided p-value < .05).

(e) significant Group (training vs. waiting list control) * Time (T1 vs. T2) interaction effect (GLM Repeated Measures, p-value < .05).

*see Appendix 6.1

Table 6.3. Effect sizes for within-group and between-group comparisons (Cohen's *d* (Cohen, 1988)) and group*time interactions (d_{ppc2} as described by Morris (2008)).

	Training vs. Healthy at T1	Waiting list vs. Healthy at T1	T1 vs. T2 for Training group	T1 vs. T2 for Waiting list group	Training vs. Waiting list at T1	Training vs. Waiting list at T2	Time*group Interaction
Tests for visual functions							
Visual acuity right eye (VOD)	-	-	0.08	0.45	0.01	0.27	0.29
Visual acuity left eye (VOS)	-	-	0.02	0.09	0.27	0.19	0.08
Contrast sensitivity*	-	-	0.24	0.22	0.06	0.47	0.42
Functional Field Score (FFS)	-	-	0.04	0.24	0.61	**0.53**	0.11
Reading tests							
Radner average reading speed (wpm)	-	-	0.23	0.03	0.20	0.36	0.13
Minimal readable text size (LogRad)	-	-	0.09	0.00	0.09	0.18	0.06
Text reading speed (wpm)	-	-	0.13	0.43	0.32	0.03	0.27
Text correct answers	-	-	0.44	0.06	0.26	0.27	0.44
Basic scanning tests							
Dot counting task							
Reaction times (ms)							
All trials (Dots-RT-all)	**0.89**	**0.72**	0.13	0.29	0.09	0.08	0.15
Few dots (Dots-RT-few)	**1.23**	**1.31**	0.28	0.49	0.07	0.17	0.06
Many dots (Dots-RT-many)	**0.66**	**0.53**	0.06	0.23	0.13	0.05	0.17
Proportion correct answers							
All trials (Dots-correct-all)	**0.87**	**0.62**	0.23	0.18	0.05	0.17	0.24
Few dots (Dots-correct-few)	0.41	**0.52**	0.10	0.20	0.30	0.23	0.04
Many dots (Dots-correct-many)	**0.88**	**0.58**	0.39	0.07	0.23	0.09	0.32
Parallel search task							
Reaction times (ms)							
All trials (Par-RT-all)	**1.97**	**2.22**	0.14	0.19	0.28	0.12	0.15
Target present (Par-RT-target)	**1.28**	**1.44**	0.21	0.38	0.08	0.01	0.07
Target absent (Par-RT-notarget)	**2.29**	**2.29**	0.11	0.02	0.37	0.16	0.18
Accuracy							
Total number of errors (Par-err)	0.04	**0.52**	0.05	0.25	**0.51**	0.36	0.26
Number of omissions (Par-omis)	0.22	**0.52**	0.10	0.22	**0.58**	0.38	0.28

	Training vs. Healthy at T1	Waiting list vs. Healthy at T1	T1 vs. T2 for Training group	T1 vs. T2 for Waiting list group	Training vs. Waiting list at T1	Training vs. Waiting list at T2	Time*group Interaction
Serial search task							
Reaction times (ms)							
All trials (Ser-RT-all)	**1.42**	**0.88**	0.16	0.15	0.31	0.03	0.27
Target present (Ser-RT-target)	**0.90**	**0.66**	0.18	0.07	0.16	0.05	0.20
Target absent (Ser-RT-notarget)	**1.71**	**0.95**	0.14	0.18	0.38	0.07	0.29
Accuracy							
Total number of errors (Ser-err)	0.20	**0.50**	0.16	0.00	0.32	0.11	0.21
Number of omissions (Ser-omis)	0.15	0.49	0.24	0.08	0.40	0.14	0.24
Hazard perception test							
Absolute error rate	**0.83**	0.33	0.43	0.26	0.42	0.21	0.20
Adapted error rate	**0.81**	0.34	0.45	0.30	0.42	0.19	0.24
Risk-index	0.14	0.36	0.05	0.26	0.25	0.01	0.25
Tracking Task							
Dual task condition							
Reaction times (ms)							
All stimuli (TT-RT-all)	**1.49**	**1.58**	0.45	0.13	0.38	**0.62**	0.28
Stimuli blind side (TT-RT-blind)	-	-	0.42	0.16	0.14	**0.52**	**0.56**
Stimuli seeing side (TT-RT-seeing)	-	-	0.21	0.47	**0.66**	**0.53**	0.14
Stimuli blind side - stimuli seeing side	-	-	0.33	0.30	0.31	0.38	**0.82**
Accuracy							
Number of faulty responses (TT-err)	0.17	0.32	0.22	0.29	**0.51**	0.15	**0.66**
Number of omissions (TT-omis)	0.35	0.44	0.20	0.28	0.09	0.46	0.37
Standard Deviation of Lateral Position (SDLP)	0.23	0.47	0.27	0.37	0.21	0.29	0.49
Mean reaction time dual task divided by mean reaction time single task (dual-to-single-task-ratio, DSR)							
All stimuli (DSR-all)	**1.58**	**1.12**	**0.70**	0.18	0.46	**0.60**	**1.03**
Stimuli blind side (DSR-blind)	-	-	0.45	0.35	**0.68**	0.48	**1.31**
Stimuli seeing side (DSR-seeing)	-	-	0.03	0.03	0.01	0.02	0.00

	Training vs. Healthy at T1	Waiting list vs. Healthy at T1	T1 vs. T2 for Training group	T1 vs. T2 for Waiting list group	Training vs. Waiting list at T1	Training vs. Waiting list at T2	Time*group Interaction
Obstacle course							
Digit Score	**0.69**	0.37	0.28	0.15	0.33	0.04	0.37
Number of contacts	**1.04**	**1.10**	**0.66**	0.36	0.23	**0.67**	0.15
PPWS	**1.31**	**1.17**	0.43	0.15	0.21	0.00	0.21
Questionnaires							
NEI-VFQ-25 total score	-	-	**0.65**	0.17	0.16	**0.76**	**0.54**
IMQ total score	-	-	**0.81**	0.16	0.13	**0.74**	**0.55**
CVD total score	-	-	**0.55**	0.07	0.09	**0.71**	**0.56**

Medium ($d > 0.50$) or large ($d > 0.80$) effects printed bold.

*see Appendix 6.1

Basic scanning tests

At T1, both the training group and the waiting list control group showed significantly higher reaction times than the healthy controls on all conditions of the dot counting test and visual search tests (all $p < .045$), except for a non-significant difference between the waiting list control group and the healthy group for counting patterns with many dots ($t(24.8) = 1.77$, $p = .089$). Compared to the healthy control group, both the training group and the waiting list control group made more errors on some, but not all conditions of the dot counting test (HEALTHY vs. P-TRAINING: Dots-correct-all: $t(44) = -2.92$, $p = .005$; Dots-correct-few: $p > .100$; Dots-correct-many: $t(44) = -2.98$, $p = .005$; HEALTHY vs. P-WAITING: Dots-correct-all: $t(32.1) = -2.09$, $p = .044$; Dots-correct-few: $t(26.1) = -1.74$, $p = .094$; Dots-correct-many: $t(46) = -1.99$, $p = .052$). With regard to the accuracy rates on the two visual search tests, no significant differences were found between the healthy control group and the patient groups (HEALTHY vs. P-TRAINING: all $p > .100$; HEALTHY vs. P-WAITING: Par-err: $F(26.6) = 1.74$, $p = .093$; Par-omis: $F(25.8) = 1.73$, $p = .096$; Ser-err: $F(46) = 1.73$, $p = .090$; Ser-omis: $F(46) = 1.70$, $p = .096$). Analysis of effect sizes showed that the differences between the healthy control group and the patient groups regarding the reaction times in all three tests were exclusively medium or large. The differences in accuracy rates between the training group and the healthy control group were large for counting patterns with many dots and all trials. The remaining differences in accuracy rates between the training group and the healthy control group were small or negligible. Differences in accuracy rates between the waiting list control group and the healthy control group were all of medium size, except for a small effect in the number of omission errors on the serial search test.

Hazard perception test

The training group had significantly higher absolute ($t(39) = 2.62$, $p = .012$) and adapted error rates ($t(39) = 2.56$, $p = .014$) than the healthy control group, but the proportion of risky errors was not different. No significant differences were found between the waiting list control group and healthy control group (all $p > .100$). With regard to the effect sizes, the differences between the training group and the healthy control group were large for absolute and adapted error rate, while the difference for risk-index was negligible. The differences between the waiting list control group and the healthy control group were exclusively small.

Tracking Task

When steering and responding to peripheral stimuli simultaneously, both patient groups had longer average reaction times than the healthy control group (HEALTHY vs. P-TRAINING: $t(46) = 5.17$, $p < .001$; HEALTHY vs. P-WAITING: $t(28.7) = 5.07$, $p \leq .001$). No significant group differences were found for SDLP and accuracy rates (all $p > .100$). While the healthy controls on average had equal reaction times for the single and dual task conditions (DSR=1.00), patients had significantly higher DSRs (HEALTHY vs. P-TRAINING: $t(32.4) = 5.34$, $p < .001$; HEALTHY vs. P-WAITING: $t(28.7) = 3.52$, $p = .001$). The differences between both patient groups and the healthy control group for average reaction times and DSRs represented large effects. The group differences for SDLP and accuracy rates were all small or negligible.

Obstacle course

The training group had lower Digit Scores than the healthy control group ($t(47) = -2.42$, $p = .020$), while no significant difference was found between the waiting list control group and healthy control group. Compared to the healthy control group, both the training group and the waiting list control group touched more obstacles (HEALTHY vs. P-TRAINING: $t(27.8) = 3.58$, $p = .001$; HEALTHY vs. P-WAITING: $t(24.6) = 3.67$, $p = .001$) and had lower PPWS (HEALTHY vs. P-TRAINING: $t(47) = -4.60$, $p < .001$; HEALTHY vs. P-WAITING: $t(46) = -4.04$, $p < .001$). The difference between the training group and the healthy control group regarding the Digit Score was of medium size, while a small difference was found between the waiting list control group and the healthy control group. The group differences for number of contacts and PPWS all represented large effects.

Training effects

Tests for visual functions

No significant group*time interaction effects were found for visual acuity, contrast sensitivity, and FFS (all $p > .100$). No significant changes between T1 and T2 were found for the training group (all $p > .100$). For the waiting list control group, the only parameter that changed significantly, was right eye visual acuity ($F(1,47) = 4.15$, $p = .047$; others : $p > .100$). All effect sizes for the group*time interaction effects and the changes within the patient groups, including the effect for right eye visual acuity, were small or negligible.

Analysis of changes in the border of the intact and blind visual field resulted in 52 comparisons between T1 and T2 for the training group (26 participants*2 eyes) and 46 for the control group. For the training group, no change was found in 27 cases, an enlargement of the visual field in 9 cases, a decrease in visual field in 12 cases, and in 4 cases part of the border shifted towards the seeing side, while another part shifted towards the blind side. For the waiting list control group, these values were not significantly different from the training group (values 15, 9, 14 and 8 respectively; $\chi^2(3) = 4.56$, $p = .207$).

Reading tests

No significant group*time interaction effects were found for average reading speed and minimal readable text size on the Radner reading chart, nor for reading speed or correct answers on the standardized reading text (all $p > .100$). Similar results were obtained when analyses were performed separately for patients with left and right HVFD (all $p > .100$). For the training group, the number of correct answers after reading the text increased ($t(23) = -2.15$, $p = .043$; P-WAITING: $p > .100$). No other significant within-group changes between T1 and T2 were found (P-WAITING: text-reading speed: $t(20) = -1.96$, $p = .064$; others: $p > .100$). Regarding the analysis of effect sizes, only small and negligible effects were found for the group*time interactions and within-group differences.

Basic scanning tests

No significant group*time interaction effects were found for the reaction times or accuracy rates on the dot counting test and the visual search tests (all $p > .100$). Within the training group, no significant changes were found between T1 and T2 (Dots-correct-many: $t(20) = -1.80$,

p = .087; other parameters all p > .100). The only significant change within the waiting list control group was a decrease in reaction time for counting patterns with few dots (t(22) = 2.33, p = .029; Par-target: t(22) = 1.82, p = .082; other parameters all p > .100). All group*time interaction effects and all differences between T1 and T2 within the patient groups were all of small or negligible size.

Hazard perception test

No group*time interaction effects were found for absolute error rate, adapted error rate or risk-index (all p > .100). Both the training group (absolute error rate: t(16) = 1.77, p = .096; adapted error rate: t(16) = 1.84, p = .085; risk-index: p > .100) and the waiting list control group (all p > .100) did not change significantly between T1 and T2 on these three parameters. The analysis of effect sizes revealed small effects for the group*time interaction. All changes between T1 and T2 were small for both patient groups, with the exception of a negligible effect for risk-index in the training group.

Tracking Task

Figure 6.4 presents data from the Tracking Task. A significant group*time interaction effect was found for the difference in reaction times between stimuli on the blind and seeing side (F(1,41) = 5.17, p = .028). However, neither the decrease in the training group, nor the increase in the waiting list control group was significant (both p > .100). No difference was found between the two patient groups regarding this parameter at T1 or T2 (both p > .100). No other significant group*time interactions were found (TT-RT-blind: F(1,41) = 3.45, p = .070; TT-err: F(1,42) = 3.41, p = .072; SDLP: F(1,41) = 3.49, p = .069; others: p > .100). A significant decrease in average reaction time (t(22) = 2.16, p = .042) and an almost significant decrease in reaction time for stimuli on the blind side (t(22) = 1.99, p = .059) were found for the training group, while no such effects were found for the waiting list control group (p > .100). On the other hand, the reaction times for stimuli on the seeing side were significantly reduced in the waiting list control group (t(20) = 2.17, p = .042), but not in the training group, noting that at T1, the training group reacted significantly faster on these stimuli than the waiting list control group. No significant within-group changes were found for accuracy rates or SDLP (all p > .100).

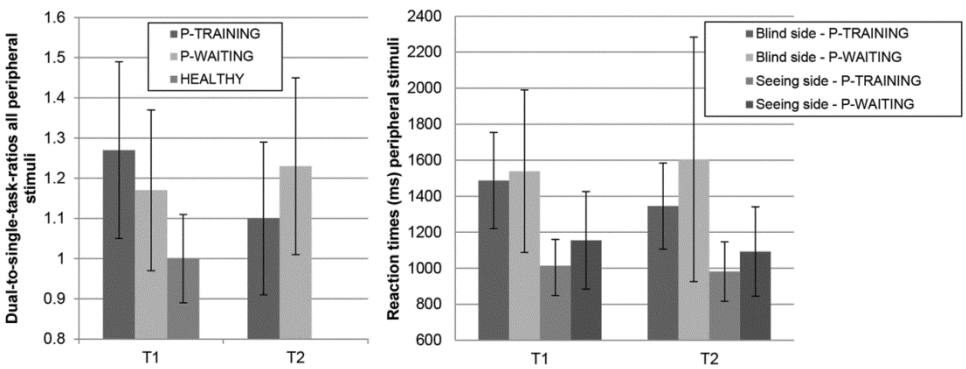


Figure 6.4. Results of the Tracking Task on T1 and T2 for the training group, waiting list control group and healthy control group (average ± SD).

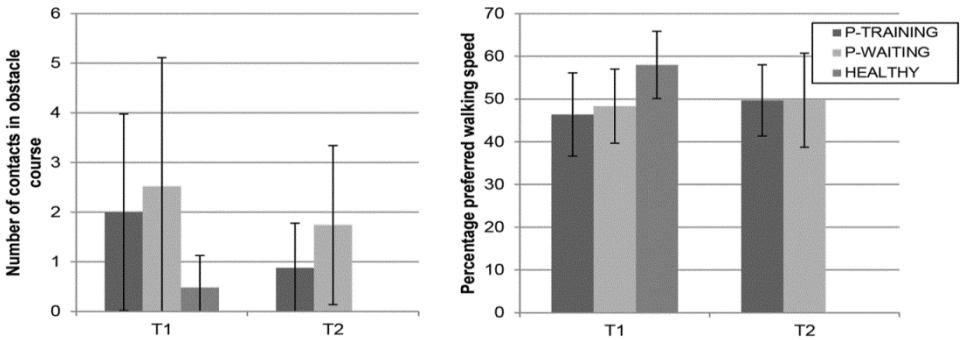


Figure 6.5. Number of contacts and Percentage Preferred Walking Speed in the obstacle course on T1 and T2 for the training group, waiting list control group and healthy control group (average ± SD).

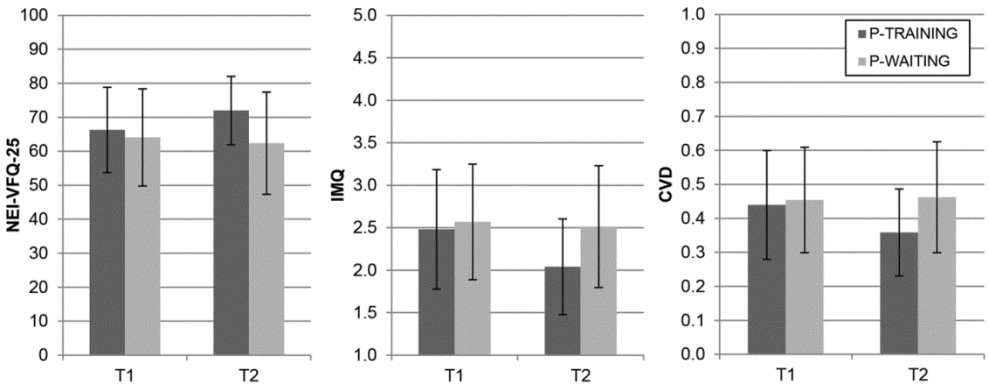


Figure 6.6. Questionnaire data on T1 and T2 for the training group and waiting list control group (average ± SD). Higher scores indicate less difficulties for NEI-VFQ-25 and more difficulties for IMQ and CVD.

With regard to the DSRs, significant group*time interaction effects were found for stimuli on the blind side ($F(1,40) = 6.71$, $p = .013$) and the total number of stimuli ($F(1,40) = 8.40$, $p = .006$). These DSRs significantly decreased for the training group (DSR-blind: $t(22) = 2.16$, $p = .042$; DSR-all: $t(22) = 3.35$, $p = .003$), while no significant changes were found for the waiting list control group ($p > .100$). While the DSR-all was not significantly different for the two patient groups at T1, this difference just missed significance at T2 ($t(41) = -1.95$, $p = .058$). The training group started with a significantly higher DSR-blind compared to the waiting list control group at T1 ($t(41) = 2.22$, $p = .032$), while there was no significant difference at T2. No significant interaction effects or within group effects were found regarding the DSR for stimuli on the seeing side ($p > .100$).

The group*time interaction effect for the difference in reaction times between stimuli on the blind and seeing side was large. The changes within the patient groups, as well as the differences between the patient groups at T1 and T2 regarding this parameter were all of small size. The interaction effects for reaction times for stimuli on the blind side and the number of

faulty responses were medium, while the remaining interaction effects had small or negligible sizes. The changes between T1 and T2 were all small for the training group and small or negligible for the waiting list control group. The interaction effects regarding DSR-all and DSR-blind were large. With regard to the DSR-all, the decrease in the training group was of medium size, while the increase in the waiting list control group was of negligible size. For the DSR-blind, both the decrease in the training group and the increase in the waiting list control group represented small changes. The group difference at T1 was small for DSR-all and medium for DSR-blind, while the group difference at T2 was medium for DSR-total and small for DSR-blind. All effects for DSR-seeing were negligible.

Obstacle course

Regarding performance in the obstacle course with cognitive load, no significant group*time interaction effects were found ($p > .100$). In the training group, however, number of contacts decreased ($t(23) = 3.24$, $p = .004$) and PPWS increased ($t(23) = -2.12$, $p = .045$) significantly after training, while no significant changes were found for the waiting list control group (contacts: $t(22) = 1.73$, $p = .098$; PPWS: $p > .100$; see Figure 6.5). Both patient groups showed no significant changes between T1 and T2 regarding the Digit Score (both $p > .100$). Analysis of the effect sizes showed that all interaction effects were small or negligible. Changes between T1 and T2 within the patient groups were all small or negligible, except for a decrease of medium effect size in the number of contacts for the training group.

Questionnaires

Figure 6.6 presents the results of the questionnaires. The group*time interaction effects revealed that training decreased the self-reported impact of the HVFD on mobility and other visually related activities of daily life, while being on the waiting list did not. The interaction effects were significant for all three questionnaires (NEI-VFQ-25: $F(1,46) = 9.74$, $p = .003$; IMQ: $F(1,46) = 8.00$, $p = .007$; CVD: $F(1,46) = 4.80$, $p = .034$). The groups did not differ from each other at T1 (all $p > .100$). Between T1 and T2, the training group improved significantly (NEI-VFQ-25: $t(25) = -3.32$, $p = .003$; IMQ: $t(25) = 4.13$, $p < .001$; CVD: $t(25) = 2.82$, $p = .009$), while the waiting list control group did not (all $p > .100$). At T2, the training group scored significantly better than the waiting list control group (NEI-VFQ-25: $t(37.7) = 2.59$, $p = .014$; IMQ: $t(47) = -2.58$, $p = .013$; CVD: $t(47) = -2.49$, $p = .017$). The group*time interactions were of medium size for all three questionnaires. The group differences were negligible at T1. Improvements between T1 and T2 in the training group represented medium (VFQ, CVD) or large (IMQ) effects, while changes in the waiting list control group were exclusively negligible. At T2, the group differences were medium for all three questionnaires.

Table 6.4. Key findings of the study.

	Comparing the patients to the healthy control group on T1	Comparing T1 and T2 for the training group and waiting list control group
Tests for visual functions		No evidence was found for changes in visual acuity, contrast sensitivity, and visual field size in both groups, except for a small, but significant improvement in right eye visual acuity for the waiting list control group.
Reading tests		No evidence was found for changes in reading performance in both groups, except for a small, but significant increase in correct answers to the questions about the text in the training group.
Basic scanning tests	Patients had higher reaction times on the dot counting test and the visual search tests. Patients made more errors when counting dots (mainly when counting many dots) compared to the healthy control group, while no significant differences were found for accuracy rates in the visual search tests.	No evidence was found for changes in performance on the dot counting test and the visual search tests in both groups, except for a small, but significant decrease in reaction times for counting patterns with few dots in the waiting list control group.
Hazard perception test	The training group had significantly higher absolute and adapted error rates than the healthy control group, but the proportion of risky errors was not different. No significant differences were found between the waiting list control group and healthy control group.	No evidence was found for changes in performance in both groups.
Tracking Task	Patients needed significantly more time to respond to the peripheral stimuli, while no significant differences were found for accuracy rates on the peripheral task and performance on the central task (SDLP). While the healthy controls on average had equal reaction times for the single and dual task conditions, patients had significantly higher in dual-to-single-task-ratios, meaning that the reaction times suffered from the dual task (i.e. the central task).	In the dual task condition, the difference in reaction times between stimuli on the blind and seeing side decreased for the training group, while it increased for the waiting list control group. The average reaction times decreased significantly in the training group, but not in the waiting list control group. These improvements in the training group did not result in higher reaction times stimuli on the seeing side, nor did it affect performance on the central and peripheral task. After training, patients seemed to be troubled less by an additional central task, according to a decrease in dual-to-single-task-ratios for stimuli on the blind side, while no effect was found for the waiting list control group.

	Comparing the patients to the healthy control group on T1	Comparing T1 and T2 for the training group and waiting list control group
Obstacle course	Patients touched more obstacles and had lower PPWS then the healthy control participants. Compared to the healthy control group, the training group had lower Digit Scores, but no significant difference was found for the waiting list control group.	In the training group, the number of contacts decreased and PPWS increased, while no significant changes were found for the waiting list control group. This improvement in the training group did not cause a decline in performance on the cognitive task that was performed during walking.
Questionnaires		According to the questionnaire data, the detrimental impact of HVFD on mobility in daily life decreased considerably in the training group, but not in the waiting list control group. Patients in the training group reported that after training, they performed more mobility-related activities with less difficulty, and they felt that their vision-related quality of life had improved.

DISCUSSION

This is the first RCT to evaluate the effects of a compensatory scanning training that is based on a systematic horizontal scanning rhythm (IH-CST). Effects were measured on basic scanning tests, a hazard perception test, an obstacle course and questionnaires on experienced difficulties in daily life, all of which were different from the training exercises. Furthermore, visual functions and reading performance were assessed before and after training. Performance of patients on the scanning and mobility-related measures at first assessment was compared to performance of a healthy control group, and performance prior to and following training was compared to performance of a patient waiting list control group. The key findings are summarized in Table 6.4.

Compared to healthy control participants, who were matched with the total patient group on age and level of education, patients with HVFD needed more time when counting dot patterns or searching for targets among distractors, needed more time to detect peripheral stimuli, especially in a dual task condition, and showed more difficulty in avoiding obstacles and maintaining preferred walking speed when walking through an obstacle course while performing a cognitive task. Evidence was found for an improvement after IH-CST on all of these tests, except for the basic scanning tests (dot counting and visual search). These results are in agreement with results from previous studies showing that patients with HVFD perform worse than healthy control participants on visual search tasks (Kasneci et al., 2014) and peripheral detection in dynamic environments (Bahnemann et al., 2015; Iorizzo, Riley, Hayhoe, & Huxlin, 2011).

According to the questionnaire data, the detrimental impact of HVFD on mobility in daily life decreased considerably after training, as indicated by significant effects, mainly of medium size. Participants reported that after training, they performed more mobility-related activities with less difficulty, and they felt that their vision-related quality of life had improved. These self-reported improvements were accompanied by improvements on some, but not all, objective outcome measures. The improvements were not mediated by improvements in visual

functions such as an increased visual field, since no considerable changes regarding the visual functions were found between T1 and T2.

Training decreased the difference in reaction times between stimuli on the blind and seeing side when patients performed a central task simultaneously, as indicated by a large and significant group*time interaction effect on the Tracking Task, although within-group changes were small and not significant. This improvement does not seem to come at the expense of the absolute reaction times for stimuli on the blind side or for stimuli on the seeing side. Furthermore, correct detection of the peripheral stimuli and performance on the central task were not negatively affected. A small, but significant within-group effect was found for a decrease in overall reaction times for the training group only. Furthermore, the reaction times for stimuli on the blind side specifically decreased in the training group and not in the waiting list control group, as indicated by an interaction effect of medium size. These results suggest that after training, patients with HVFD spread their visual attention more evenly across the left and right side, while still paying attention to the situation in front. In mobility situations in particular, it is of high importance that information from both the left and right side as well as from what is happening in front of the person, is being perceived and processed efficiently.

After training, patients with HVFD seem to be troubled less by an additional central task, as indicated by large and significant group*time interaction effects for the dual-to-single-task-ratios for the total number of peripheral stimuli and for stimuli on the blind side specifically (Tracking Task). Patients who received training showed significant decreases of medium and small size respectively for these two dual-to-single-task-ratios. Results of the obstacle course showed that after training, patients touched fewer obstacles when walking through a standardized obstacle course and performing a cognitive task simultaneously. This improvement was not at the expense of performance on the cognitive task or walking speed. In fact, PPWS increased significantly after training, meaning that the impact of obstacles and cognitive load on walking speed decreased, although the effect was only small. These findings suggest that compensation in dual task conditions becomes easier after IH-CST. Although patients with HVFD often know they should compensate by looking towards the blind side, this may be very hard in dual task situations such as having a conversation while walking, because the second task limits the attentional capacity available for compensatory scanning or because compensatory scanning efforts impair performance on the second task. The present findings suggest that after training, the skill of applying the systematic scanning rhythm was automatized, at least to some extent, increasing free attentional capacity for other tasks.

No effects of training were found for the dot counting test and the visual search tests. Apparently, the scanning rhythm as taught in the IH-CST was not very helpful during tasks that require visual counting or visual search. When searching for a predefined target in a complex display, such as a shelf in a shop, a large saccade towards the blind side may help to get a first overview, but in case of complex displays requiring serial search, every object or feature has to be watched separately. A spatially organized search pattern might then be preferred. As opposed to the IH-CST, the CST programs in the previous RCT studies (Aimola et al., 2014; Lane et al., 2010; Moedden et al., 2012; Roth et al., 2009; Schuett et al., 2012) were all based on searching for targets among distractors and they consistently found improvements on visual search tests after training.

With regard to the accuracy scores of the hazard perception test, no evidence for an effect of training was found. As suggested by Aimola and colleagues (2014), who also failed to find an effect of CST on a similar test, hazard perception supposedly requires skills beyond eye-movement strategies. Decisions on which action to perform in a specific situation may rely on other factors, such as driving experience and personality traits. In the current study, participants were likely to have perceived the whole picture after the presentation time of eight seconds, which is a long period even in the case of inefficient scanning. Future research on eye tracking data could include analysis of the time participants need before they fixate on areas of interest presenting potential hazards.

No effect of training on reading performance was found, except for a small, but significant increase in correct answers after reading a standardized text in the training group. The absence of an effect on reading speed is not surprising, since small and precise saccades are necessary during reading, while the scanning strategy as applied in the IH-CST consists of large saccades towards the far periphery. These findings correspond to the results of previous RCTs on CST (Aimola et al., 2014; Lane et al., 2010; Moedden et al., 2012; Roth et al., 2009; Schuett et al., 2012). Reading performance was assessed in all four studies, but an improvement in reading was only found after training programs including reading exercises (Aimola et al., 2014; Schuett et al., 2012).

In summary, the present findings show that the IH-CST, which is based on learning to apply a top-down, systematic horizontal scanning strategy, specifically improves detection of peripheral stimuli in mobility situations, without limiting, or even improving simultaneously performed activities. No evidence was found for improvements on dot counting, visual search or reading. The relative specificity of the training effect is in accordance with the findings of previous RCT studies on visual search training, which mainly found effects on tests similar to the exercises practiced during training. Schuett (2012), for example, found that CST with visual search exercises only improved visual search while reading training only improved reading performance, indicating that the training effects were specific and task-dependent. Aimola and colleagues (2014) also reported that the effects of CST were restricted to tasks that resembled the training exercises.

In contrast to these previous studies, the present study found evidence for a transfer of training effects to activities that were different from the exercises applied during training. However, IH-CST only improved mobility-related activities in which detection of peripheral stimuli is important, while no improvement was found on tests that require other visual skills, such as reading and, apparently, visual search. The finding that CST based on visual search exercises caused specific improvements on visual search tests, while the IH-CST based on a systematic scanning rhythm did not cause such an effect, also suggests that different scanning strategies are required for visual search as for detecting peripheral information. Hardies and colleagues (2010) found evidence for different compensatory strategies being helpful for different types of scanning tasks.

This is the first RCT to find an improvement of CST on mobility performance. Of all studies examining the effects of CST with exercises of horizontal scanning using a within-subject design, only Tant (2002) included mobility assessments and they found an improvement in visual-spatial performance during driving. The study of Aimola and colleagues (2014) is the only

RCT besides the present study that analyzed the transfer of the training effect to objective mobility-related tests. However, their CST was based on unsupervised reading training and CST with visual search exercises and no improvement was found for walking speed in an obstacle course. This suggests that the training of horizontal scanning strategies has a higher potential for improving mobility in daily life than the training of visual search strategies. This suits the idea that engaging in traffic does not so much rely on searching for specific targets, while early detection of all relevant objects is essential for anticipation in the dynamic traffic situations. Furthermore, the improvement on mobility-related tests as found in the present study suggests high importance of certain training characteristics, such as a specific top-down scanning strategy, training exercises with targets in the far periphery (beyond 40 degrees from the midline), feedback of a therapist, and inclusion of exercises in daily life mobility situations, none of which were included in the training examined by Aimola and colleagues (2014). At present, the data cannot tell which of these characteristics are most important or if it is the combination of these characteristics that is valuable. Furthermore, the present data cannot tell to what degree the face-to-face training and the homework assignments have contributed to the improvements.

A few remarks to the present study: Although an RCT design with a waiting list control group controls for maturation and testing effects, the risk of placebo effects remains. The degree to which the intensive attention and support from the therapist influenced performance of the patients cannot be determined. The specificity of the present results, however, suggests that the improvements are not merely non-specific placebo effects. The mobility-related activities improved specifically, even though these activities were different from the training exercises. The small sample sizes might have prohibited the detection of further effects, however, the exclusively negligible and small sizes of the effects on dot counting and visual search indicate that there is presumably no effect of the IH-CST on these tasks. Therefore, the inclusion of larger sample sizes will presumably also not reveal such effects. It cannot be not ruled out, however, that a higher number of training sessions could have resulted in improvements on the other tests, such as the dot counting test. Another factor that possibly influenced the outcome of the training are the differences in performance at T1 between the two patient groups that was found for some tests. This might have contributed to failure in detecting certain effects. The finding that none of the significant group*time interaction effects could be fully explained by a significant between-group difference at T1 argues against type I errors. Unfortunately, analyses of eye tracking data could not be performed in the present study. Including analyses of eye tracking data in future studies might provide more insight into the question which scanning mechanisms are specifically helpful for different types of visual tasks. Another suggestions for future research on the CST is to examine whether specific components of the IH-CST protocol are more useful than others, which might be related to individual differences in patient characteristics or rehabilitation goals.

In conclusion, the IH-CST trains patients with HVFD to apply a systematic scanning rhythm, which helps them to compensate for their visual field defect in specific tasks with specific demands, mainly detection of peripheral stimuli in mobility situations. This skill is practiced under supervision of a therapist in a step-by-step manner, from simple scanning exercises to

practicing the scanning rhythm in high-demanding mobility situations of daily life. This skill is automatized as much as possible, in order to benefit in daily life situations, which are often dual task situations. After training, participants indeed felt less impaired in mobility situations. These self-reported improvements were accompanied by improvements in detecting peripheral stimuli and avoiding obstacles during walking, especially in dual task situations in which a second task limits the attentional capacity available for compensatory scanning. The results indicate that reading, but also searching for a target amongst distractors, requires different compensatory scanning mechanisms than fast detection of peripheral stimuli in mobility situations. In previous literature, the terms visual search and visual exploration have been used for a wide range of different visual tasks. Professionals involved in the research, development and application of scanning training for HVFD patients are advised to consciously reflect on which type of compensatory scanning strategy is appropriate for the specific activity they aim to examine or improve.

Acknowledgements

The authors gratefully acknowledge all participants, as well as the staff from Royal Dutch Visio and Bartiméus involved in participant recruitment and training. Special thanks goes out to occupational therapists Birgit van Iddekinge and Marie-Louise Kamps of Royal Dutch Visio, Haren, The Netherlands, for supervising the occupational therapists involved in training the participants. We thank orthoptist Nadine Naumann of Royal Dutch Visio, Haren, The Netherlands, for analyzing the perimetry plots.

APPENDIX 6.1: ERRATUM VALUES CONTRAST SENSITIVITY

After publishing the original paper, we discovered that an older version of the GECKO chart was used in the study. However, we had used the values for peak contrast sensitivity corresponding to the new GECKO chart. Therefore, the correct values slightly deviate from the published values. A notification has been sent to the journal that published the original paper.

Erratum Table 6.2. Test scores (mean ± SD).

	Training group			Waiting list control group		
	n	T1 (Before training)	T2 (After training)	n	T1 (Early pre-assessment)	T2 (Before training)
contrast sensitivity: as presented in Table 2 of original paper	26	2.08 ± 0.21	2.13 ± 0.12	23	2.07 ± 0.17	2.04 ± 0.27
contrast sensitivity: correct values	26	1.94 ± 0.16	1.97 ± 0.08	23	1.93 ± 0.13	1.90 ± 0.19

Note: The change in values does not lead to a change in the results of the analyses regarding contrast sensitivity. In both cases, no significant differences were found between the two patient groups, neither at T1, nor at T2. Also, in both cases, no significant differences were found between T1 and T2 for both groups. Furthermore, in both cases, no significant group*time interaction effects were found.

Erratum Table 6.3. Effect sizes for within-group and between-group comparisons.

	T1 vs. T2 for Training group	T1 vs. T2 for Waiting list group	Training vs. Waiting list at T1	Training vs. Waiting list at T2	Time*group Interaction
contrast sensitivity: as presented in Table 3 of original paper	0.24	0.22	0.06	0.47	0.42
contrast sensitivity: correct values	0.27	0.22	0.06	0.50	0.43

7

The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: further support, predictive variables and follow-up

De Haan, G. A., Melis-Dankers, B. J. M., Brouwer, W. H., Tucha, O., & Heutink, J. (in revision). The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: further support, predictive variables and follow-up. *PloS One.*

ABSTRACT

Introduction: People with homonymous visual field defects (HVFD) often report difficulty detecting obstacles in the periphery on their blind side in time when moving around. Recently, a randomized controlled trial showed that the IH-CST program specifically improved detection of peripheral stimuli and avoiding obstacles when moving around, especially in dual task situations.

Method: The within-group training effects of the previously reported IH-CST are examined in an extended patient group. Performance of patients with HVFD on a pre-assessment, post-assessment and follow-up assessment and performance of a healthy control group are compared. Furthermore, it is examined whether training effects can be predicted by demographic characteristics, variables related to the visual disorder, and neuropsychological test results.

Results: Performance on both subjective and objective measures of mobility-related scanning was improved after training, while no evidence was found for improvement in visual functions (including visual fields), reading, visual search and dot counting. According to the participants, the positive effects were still present six to ten months after training. No demographic characteristics, variables related to the visual disorder, and neuropsychological test results were found to predict the size of training effect, although some evidence was found for more improvement in patients with left-sided HVFD than in patients with right-sided HFVD.

Conclusion: Further support was found for a positive effect of IH-CST on detection of visual stimuli during mobility-related activities specifically. Based on the reports given by patients, these effects appear to be long-term effects. However, self-reported improvement did not correlate with improvement in objective mobility performance. Therefore, no conclusions can be drawn on the objective long-term training effects.

INTRODUCTION

Homonymous visual field defects (HVFD) are caused by postchiasmatic brain damage and in most cases do not fully recover (Ali et al., 2013; Pambakian & Kennard, 1997; Zhang et al., 2006b). People with HVFD often report difficulty detecting obstacles located in the blind periphery in time when moving around. This may result in feelings of insecurity and even in collisions and may have a serious impact on participation in society (De Haan, Heutink et al., 2015, chapter 4).

Several training programs have been developed aimed at optimal compensation for the HVFD by adapting eye movements. One of these, the IH-CST (InSight-Hemianopia Compensatory Scanning Training), trains patients to apply a systematic, wide horizontal scanning rhythm. Recently, a randomized controlled trial (RCT) (De Haan, Melis-Dankers, Brouwer, Tucha, & Heutink, 2015, chapter 6 of this thesis) showed that the IH-CST specifically improves detection of peripheral stimuli and avoiding obstacles when moving around, especially in dual task situations. No evidence was found for an improvement in visual functions (including visual field size), reading or searching for targets on a display.

In this paper, the within-group effects of the IH-CST are analyzed in a larger patient group than in the previously reported RCT (chapter 6). Performance of patients with HVFD at the pre-assessment and post-assessment are compared with the performance of a healthy control

group. The results of a follow-up assessment are reported, as well as the associations between subjective and objective performance. Furthermore, it will be examined whether the changes between the pre-assessment and post-assessment can be predicted by demographic characteristics, variables related to the visual disorder, and neuropsychological test results. As concluded in a recent systematic review of the literature on HVFD (De Haan et al., 2014, chapter 3), more research is needed on the predictive variables of training effects. Knowing which variables are related to the effects of training would enable rehabilitation workers to deploy the best rehabilitation program for the individual patient. This may improve efficacy of rehabilitation. In short, the aim of the present study is to examine the effects of IH-CST in terms of subjective and objective mobility-related measures, including the long-term effects and the influence of several factors on the effect of training.

MATERIALS AND METHODS

Descriptions of the participant recruitment, training protocol and assessment measures are described in more detail in chapter 6.

Ethics

The Medical Research Ethics Committee of the University Medical Center Groningen (registration number METc 2010/078) and the relevant patient organizations approved the study protocol. The study was performed in accordance with the 2008 Declaration of Helsinki. Informed written consent was provided by all participants.

Participant recruitment

Patients with a unilateral HVFD caused by acquired postchiasmatic brain injury were recruited at Royal Dutch Visio and Bartiméus, the two centers of expertise for blind and partially sighted people in the Netherlands. Patients were included if standardized ophthalmological testing confirmed the presence of a HVFD, existing for at least five months, minimum binocular visual acuity of Snellen 0.5 (6/12 or 20/40, LogMAR 0.3) and intact eye and head motility. A stable neurological and ophthalmological condition was required and patients had to be able to walk at least 50 meters independently. Furthermore, standardized neuropsychological testing was performed at Royal Dutch Visio or Bartiméus, in order to examine visual perceptual functions as well as cognitive status. Patients with severe (neuro)psychological disorders, such as neglect, or psychiatric conditions, such as anxiety disorders, were excluded from participation in the study. The MMSE score had to be ≥ 24. The results from this neuropsychological testing were collected for further analyses in case the patient was included in the study.

Healthy control participants responded to public announcements and received a financial incentive. Inclusion criteria for the healthy control group were the absence of visual, physical, neurological or psychological impairments, as confirmed by the participants during an interview. A binocular visual acuity of at least Snellen 0.8 (6/7.5 or 20/25, LogMAR 0.1) was required and their MMSE score had to be ≥ 24. The healthy control participants were matched with the patient group on age and level of education.

Design

Patients were assessed in the week before onset of training (T-pre) and after 13 weeks of training T-post). Training was extended with a number of sessions after T-post, i.e. outside the scope of this study, in case the individual mobility goals were not fully reached after 13 weeks of training. During a follow-up assessment (FU) six to ten months after T-post, questionnaires were administered measuring the impact of the HVFD on daily living. The scanning and mobility-related tests included in T-pre and T-post were also administered in a healthy control group. The healthy controls performed these tests however only once.

In the context of the previous RCT (chapter 6), half of the patient sample (which served as waiting list control group) had participated in an early pre-assessment, at which they performed the same tests as on T-pre and T-post. After 13 weeks on a waiting list, they participated in T-pre, followed the same training program as the remaining patients, and participated in T-post and FU. The full study design is presented in Appendix 7.1. The participant group described in this report is the same as described in the article on the RCT (chapter 6). Pooling the data from both patient groups of the RCT increased the number of patients that received training and therefore increased the power to detect potential improvements or decrements of performance.

Training

All patients underwent the IH-CST (InSight-Hemianopia Compensatory Scanning Training) between T-pre and T-post. The main focus of the IH-CST was on learning a systematic, anticipatory scanning rhythm that could be applied in a wide range of mobility-related activities.

The training program contained exercises aimed at improvement of awareness of the visual field defect and its consequences for daily life, learning to apply a predefined systematic scanning rhythm, and practice of the scanning rhythm in daily life mobility situations. The scanning rhythm consisted of a triad of horizontal eye movements. First, a large saccade from the center towards the blind side was made, in order to shift the visual field defect and to receive the visual information from the periphery. Then a second saccade was made back towards the seeing side to prevent overcompensation. Third, a small saccade was made back to the center. This scanning pattern was repeated at a speed matching the environmental demands and speed of moving around.

The IH-CST was developed at Royal Dutch Visio. Training was provided by occupational therapists at one location of Bartiméus and nine locations of Royal Dutch Visio in the Netherlands. The IH-CST consisted of 15 sessions (18.5 hours of face-to-face training, plus homework assignments) during a period of 10 weeks.

Assessments

Assessment procedure

The assessments were performed at the University Medical Center Groningen, the Netherlands. All participants were tested individually. Training for the patient group was provided between March 2010 and October 2012. The results of the assessments had no influence on the way the patient was treated at the rehabilitation center; data were

anonymized and not provided on the individual level to Royal Dutch Visio or Bartiméus. The healthy control group started with the test for visual acuity and the MMSE and continued only if the inclusion criteria were met with regard to these tests. Participants in this group performed the tests related to scanning and mobility, with similar setup and instructions as the patient group. Assessments of the healthy control group took place between October and December 2012. All patients were approached for a follow-up six to ten months after T-post. The same questionnaires as included in T-pre and T-post were administered via telephone by research assistants who were not involved in data analyses. The follow-up assessments were performed between May 2011 and May 2013.

Tests for visual functions

Monocular visual acuity was measured with the ETDRS 2000 Letter Chart (Ferris et al., 1982) and peak contrast sensitivity was tested with the Gecko Test (Kooijman et al., 1994). Goldmann perimetry (isopters V-4, III-4 and I-4) was used to plot the monocular visual fields. Size of the intact binocular visual field was calculated and expressed in Functional Field Size (American Medical Association, 2008; Langelaan et al., 2005). Furthermore, it was analyzed whether the border between the blind and intact area had shifted more than 5 degrees between T-pre and T-post. The tests for visual functions were only administered in the patient group. For the healthy control group, it was only checked if binocular visual acuity was higher than Snellen 0.8 (6/7.5 or 20/25, LogMAR 0.1).

Reading tests

Reading speed, minimal readable text size, and comprehension of the text were assessed with the Radner reading chart (Maaijwee et al., 2007; Radner et al., 1998) and with a text of approximately 400 words (three standardized parallel versions).

Basic scanning tests

Three basic scanning tests were administered, presenting the stimuli on a large screen (40° horizontally and 33° vertically, viewing distance 192 cm). In the dot counting test, participants were asked to count dot patterns as quickly and as correct as possible. Half of the trials contained few dots (between 6 and 9 dots), while the other half contained many dots (between 18 and 21 dots). In the parallel search test, participants had to indicate whether or not the target letter O was present among T's, again as fast and accurate as possible. In the serial search test, participants indicated whether the target letter G was present among C's. Reaction times and accuracy scores were recorded.

Hazard perception test

Photos of traffic situations were presented on a large screen (40° horizontally by 25° vertically, viewing distance 192 cm). Participants were asked to carefully view the photos, each presented for eight seconds, and decide whether they would brake, release the accelerator or keep the same speed (i.e., no intervention), imagining that they were positioned in the driver's seat. The number of incorrect responses (absolute error rate) was recorded. Two other parameters were calculated taking the type of errors into account. The adapted error rate was defined by the

sum of the incorrect responses, but very risky responses ("no intervention" when the correct response is "braking") and very cautious responses ('braking" when the correct response is "no intervention") were counted double. The risk-index reflected the proportion of risky answers in the adapted error rate (risk-index = (risky responses + 2*very risky responses) / adapted error rate). The hazard perception test is described in more detail by Vlakveld (2011) and in chapter 6.

Tracking Task

In the single task condition of the Tracking Task, participants had to indicate as fast and accurate as possible the pointing direction of arrows that were presented in the left or right periphery. In the dual task condition, a second task was added. While responding to the peripheral targets, participants simultaneously had to perform a steering task. On a monitor in front, a straight road was presented, on which they were driving with fixed speed. Because of an imaginary cross-wind, they had to attend to the screen continuously and correct their lateral position on the road using a steering wheel. The Tracking Task is described in more detail by Brouwer (2002) and in chapter 6. Outcome parameters were number of omissions (no response to stimulus), number of errors (incorrect response to stimulus) and reaction times for the peripheral stimuli, and the standard deviation in lateral position on the road (SDLP), all from the dual task condition. Dividing the mean reaction time in the dual task condition by the mean reaction time in the single task condition resulted in the dual-to-single-task-ratio (DSR).

Obstacle course

A standardized obstacle course was used to examine the influence of obstacles and cognitive load on walking speed. First, preferred walking speed was measured in an obstacle-free corridor. Subsequently, participants walked through the empty corridor again, but this time they had to repeat verbally presented series of digits during their walk (i.e., with cognitive load; cognitive dual task). After that, the corridor was filled with obstacles and participants walked through the course once with cognitive load and once without cognitive load. Included in the analyses were the number of contacts with obstacles and the Digit Score (proportion correct answers on the digit series) during the walk through the obstacle course. Furthermore, percentage preferred walking speed was included (PPWS = (walking speed in obstacle course with cognitive load / walking speed in empty corridor with cognitive load) * 100).

Questionnaires

The impact of the HVFD on activities and participation in daily life was assessed using the Independent Mobility Questionnaire (IMQ) (Turano et al., 1999), the Visual Functioning Questionnaire (NEI-VFQ-25) (Mangione et al., 2001; Van der Sterre et al., 2001), and the Cerebral Visual Disorders questionnaire (CVD; described by Kerkhoff and colleagues (1990) and by Dittrich, 1996, as cited by Tant (2002), p.75). The three total scores of the questionnaires were included in the analyses. For the IMQ and CVD, higher scores indicate more difficulty as experienced by the patient. For the NEI-VFQ-25, higher scores mean less difficulty experienced in daily life.

Analysis

Differences in participant characteristics between the patient group and the healthy control group were analyzed with two-tailed independent samples t-tests for age and level of education and a two-tailed Chi-Square Test for gender.

To compare test performance of the patient group at T-pre and at T-post with test performance of the healthy control group, two-tailed independent samples t-tests were used. Change within the patient group between T-pre and T-post was examined with two-tailed matched pairs t-tests. For the questionnaire data in the patient group, the results of T-pre, T-post, and FU were compared in a General Linear Model (GLM) Repeated Measures analysis, with simple contrasts comparing T-pre with FU and T-post with FU. In case Levene's test showed that the assumption of equal variances could not be assumed for a t-test, the unequal-variance t-test was used. Missing values were excluded pairwise. Significant effects were defined by *p*-values < .05. *P*-values are reported in case of a *p*-value < .10. Cohens's *d* was used for calculating the effect sizes of the between-group and within-group comparisons (Cohen, 1988). Effect sizes were classified as negligible ($d < 0.20$), small ($0.20 < d < 0.50$), medium ($0.50 < d < 0.80$) or large ($d > 0.80$).

Four parameters related to scanning in mobility situations were further examined. These outcome parameters were found to improve by IH-CST in the RCT analysis (chapter 6). The total score on the IMQ reflected the experienced difficulty in several mobility situations as reported by the patients, reaction time to peripheral stimuli in the dual tracking task (TT-RT-all) was an indication of the level of compensation regarding detection of information in the periphery, the DSR in the tracking task (DSR-all) represented the influence of a secondary task on efficiency of scanning, and PPWS represented a measure of the ability to detect and avoid obstacles during walking. First, Pearson's correlations were used to examine how self-reported mobility performance was related to test performance. Then, a linear regression analysis was performed for each of the outcome parameters to examine the associations between training effects and a number of demographic characteristics, variables related to the visual disorder, and neuropsychological test results. The absolute difference between T-pre and T-post was chosen as the independent variable, because the aim was to examine which parameters predict how much a patient benefits from training. The independent variables, including score of the outcome parameter on T-pre, were inserted stepwise. Listwise exclusion in case of missing values would have led to few remaining data. Therefore, multiple imputation (Baraldi & Enders, 2010; Schafer & Graham, 2002) was applied for the missing values among the independent variables. This created multiple datasets (set to five) with different values for the originally missing values. Each regression analysis was then performed on each of these five datasets, resulting in one final model in which the five outcomes were pooled back together.

RESULTS

Participants

Nine of the 54 included patients with HVFD dropped out of the study after T-pre. One patient had deceased and other reasons for drop-out were health problems ($n = 2$), difficulties scheduling the training or assessment ($n = 2$), or too low compliance with the training protocol ($n = 4$). For 35 of the remaining patients, brain infarction was the cause of the HVFD. Other

Table 7.1. Summary of participant characteristics (numbers, mean ± SD, range).

	Patient group (n = 45)	Healthy group (n = 25)	p-value
Gender	30 men, 15 women	7 men, 18 women	.003 [a] (Chi^2 Test)
Age	55 ± 10.9 [27;74]	53 ± 14.5 [28;76]	.530 (t-test)
Level of education [b]	5.4 ± 0.8 [4;7]	5.5 ± 0.8 [4;7]	.494 (t-test)
Side of HVFD	31 left HVFD, 14 right HVFD		
Functional Field Size	60 ± 9.1 [44;80], 10 quadrantanopia 35 hemianopia		
Time since onset of HVFD (months)	22 ± 24.4 [5;122]		

[a] Significant difference between the patient group and the healthy control group ($p < .05$).

[b] Level of education according to Verhage (Duits & Kessels, 2006); higher values represent higher levels of education.

causes of the HVFD were hemorrhagic vascular accident (*n* = 3), traumatic brain injury (*n* = 2), penetrating head trauma (*n* = 1), extirpation of arteriovenous malformation with postoperative hemorrhage (*n* = 1), or combined etiology (*n* = 3). For 19 patients, T-pre was the second time they performed the tests. These patients had participated in the early pre-assessment 13 weeks prior to start of the training as part of the RCT (chapter 6, Appendix 7.1). Table 7.1 summarizes the participants' characteristics. There were relatively fewer men in the healthy control group compared to the patient group ($\chi^2(1) = 9.64$, $p = .003$).

Royal Dutch Visio provided training for forty-four patients and Bartiméus for one patient. Training was extended after T-post for 10 patients. Time between neuropsychological testing and T-pre was on average 19 weeks (range 2-68 weeks). For one patient, time between T-pre and T-post was 16 instead of 13 weeks, because of difficulties rescheduling T-post). Follow-up data could not be collected for two patients; one patient was not willing to participate and one patient had deceased between T-post and FU. For two other patients, time between T-post and FU exceeded 10 months (11 and 15 months respectively).

Training effects

Mean test scores and standard deviations, as well as effect sizes corresponding to the different t-tests are presented in Table 7.2.

Table 7.2. Mean test scores (SD) and effect sizes for group differences (absolute values).

	Test scores						Effect sizes		
	Healthy control group		Patient group before training (T-pre)		Patient group after training (T-post)		Patient group T-pre vs. Healthy control group	Patient group T-pre vs. T-post	Patient group T-post vs. Healthy control group
	n	mean (*SD*)	n	mean (*SD*)	n	mean (*SD*)			
Tests for visual functions									
Visual acuity right eye	-		45	0.94 (0.27)	45	0.93 (0.26)	-	0.04	-
Visual acuity left eye	-		45	0.97 (0.25)	45	0.96 (0.24)	-	0.05	-
Peak contrast sensitivity	-		45	1.93 (0.16)	45	1.94 (0.15)	-	0.08	-
Functional Field Score	-		45	59.83 (9.14)	45	59.40 (9.01)	-	0.08	-
Reading tests									
Radner average reading speed (wpm)	-		43	151.4 (32.56)	43	156.2 (35.94)	-	0.23	-
Minimal readable text size (LogRad)	-		43	0.07 (0.14)	43	0.08 (0.11)	-	0.17	-
Text reading speed (wpm)	-		42	134.7 (28.58)	42	135.6 (28.59)	-	0.05	-
Text correct answers	-		43	1.51 (0.59)	43	1.67 (0.47)	-	0.22	-
Basic scanning tests									
Dot counting test									
Reaction times (ms)									
All trials	25	6631 (1496)	40	**8634 (3255) a**	40	**8132 (3242) a**	**0.74**	0.17	**0.55**
Few dots	25	3214 (818)	40	**4832 (1870) a**	40	**4576 (1837) a**	**1.04**	0.16	**0.89**
Many dots	25	10048 (2347)	40	**12427 (5071) a**	40	11700 (5120)	**0.56**	0.16	0.39
Proportion correct answers									
All trials	25	0.84 (0.12)	40	**0.74 (0.20) a**	40	**0.75 (0.18) a**	**0.60**	0.13	**0.54**
Few dots	25	0.96 (0.07)	40	0.91 (0.18)	40	0.92 (0.17)	0.34	0.04	0.31
Many dots	25	0.72 (0.21)	40	**0.56 (0.28) a**	40	0.59 (0.27)	**0.62**	0.14	**0.51**
Parallel search test									
Reaction times (ms)									
All trials	25	1196 (367)	40	**2264 (687) a**	40	**2142 (720) a**	**1.82**	0.17	**1.55**
Target present	25	996 (260)	40	**1477 (481) a**	40	**1382 (397) a**	**1.17**	0.22	**1.10**
Target absent	25	1396 (504)	40	**3049 (936) a**	40	**2904 (1091) a**	**2.07**	0.13	**1.65**

	Test scores						Effect sizes		
	Healthy control group		Patient group before training (T-pre)		Patient group after training (T-post)		Patient group T-pre vs. Healthy control group	Patient group T-pre vs. T-post	Patient group T-post vs. Healthy control group
	n	mean (*SD*)	n	mean (*SD*)	n	mean (*SD*)			
Accuracy									
Total number of errors	25	0.48 (0.77)	39	0.64 (1.33)	39	0.49 (0.79)	0.14	0.14	0.01
Number of omissions	25	0.32 (0.63)	39	0.44 (1.23)	39	0.36 (0.74)	0.12	0.09	0.06
Serial search test									
Reaction times (ms)									
All trials	25	3498 (1337)	40	**5443 (1982) a**	40	**5177 (1733) a**	**1.10**	0.18	**1.05**
Target present	25	2600 (1321)	40	**3750 (1588) a**	40	**3634 (1309) a**	**0.77**	0.11	**0.79**
Target absent	25	4395 (1474)	40	**7136 (2625) a**	40	**6721 (2343) a**	**1.21**	0.20	**1.13**
Accuracy									
Total number of errors	25	0.84 (1.38)	40	1.23 (1.63)	40	1.70 (1.91)	0.25	0.22	**0.50**
Number of omissions	25	0.76 (1.39)	40	1.10 (1.41)	40	1.48 (1.77)	0.24	0.21	0.44
Hazard perception test									
Absolute error rate	24	8.50 (2.21)	36	9.36 (2.79)	36	8.83 (2.54)	0.33	0.19	0.14
Adapted error rate	24	9.21 (2.89)	36	10.50 (3.48)	36	9.64 (2.94)	0.40	0.28	0.15
Risk-index	24	0.76 (0.18)	36	0.72 (0.17)	36	0.75 (0.16)	0.19	0.14	0.07
Tracking Task									
Dual task condition									
Reaction times (ms)									
All stimuli (TT-RT-all)	25	943 (147)	41	**1219 (266) a**	41	**1135 (231) a,b**	**1.21**	0.36	**0.94**
Stimuli blind side	-		41	1530 (505)	41	**1332 (338) b**	-	0.48	-
Stimuli seeing side	-		41	1047 (204)	41	1015 (237)	-	0.18	-
Stimuli blind side - stimuli seeing side	-		41	483 (399)	41	**318 (309) b**	-	0.44	-
Accuracy									
Number of faulty responses	25	0.84 (1.07)	42	0.71 (0.97)	42	0.86 (0.93)	0.13	0.13	0.02
Number of omissions	25	0.04 (0.20)	42	0.45 (1.31)	42	**0.10 (0.37) b**	0.39	0.32	0.19
Standard Deviation of Lateral Position (SDLP)	25	46.1 (6.50)	40	48.2 (10.72)	40	49.4 (10.49)	0.22	0.14	0.35

	Test scores						Effect sizes		
	Healthy control group		Patient group before training (T-pre)		Patient group after training (T-post)		Patient group T-pre vs. Healthy control group	Patient group T-pre vs. T-post	Patient group T-post vs. Healthy control group
	n	mean (*SD*)	n	mean (*SD*)	n	mean (*SD*)			
Mean reaction time dual task divided by mean reaction time single task (dual-to-single-task-ratio, DSR)									
All stimuli (DSR-all)	25	1.00 (0.11)	40	**1.25 (0.22) a**	40	**1.14 (0.21) a,b**	**1.35**	0.48	**0.79**
Stimuli blind side	-		40	1.56 (0.53)	40	**1.30 (0.41) b**	-	0.42	-
Stimuli seeing side	-		40	1.07 (0.19)	40	1.07 (0.19)	-	0.02	-
Obstacle course									
Digit Score	25	0.79 (0.24)	43	**0.64 (0.30) a**	43	0.68 (0.30)	**0.56**	0.21	0.42
Number of contacts	25	0.48 (0.65)	43	**1.74 (1.79) a**	43	**0.74 (1.03) b**	**0.85**	**0.68**	0.29
PPWS	25	58.0 (7.88)	43	**48.1 (10.32) a**	43	**50.6 (9.39) a,b**	**1.04**	0.34	**0.84**
Questionnaires									
NEI-VFQ-25 total score	-		45	64.38 (14.00)	45	**71.03 (11.40) b**	-	**0.59**	-
IMQ total score	-		45	2.52 (0.71)	45	**2.08 (0.51) b**	-	**0.75**	-
CVD total score	-		45	0.46 (0.16)	45	**0.36 (0.13) b**	-	**0.58**	-

(a) significant difference between patient group and healthy control group (independent sample t-test; two-sided p-value <.05).

(b) significant difference between T-pre and T-post within patient group (matched pairs t-test; two-sided p-value <.05).

Tests for visual functions
For the visual functions tests, no significant differences were found between T-pre and T-post (all $p > .100$, all negligible effect sizes).

Reading tests
No significant differences were found on the reading tests between T-pre and T-post (all $p > .100$, all negligible effect sizes, except for small increases in Radner mean reading speed and correct answers of the standardized text). When analyses were performed separately for patients with left and right HVFD, similar results were obtained (all $p > .100$).

Basic scanning tests
At T-pre, all reaction time parameters of the basic scanning tasks were significantly higher for the patients than for the healthy controls. For most of these parameters, the difference was still present at T-post (all $p > .014$, all medium and large effect sizes). Only the counting of many dots was no longer significantly slower in patients than in healthy controls at T-post ($t(58.8) = 1.77$, $p = .083$, small effect size). No significant differences were found for the reaction times between T-pre and T-post in the patient group (all $p > .100$, all small or negligible effect sizes).

With regard to the accuracy rates on the dot counting test, patients made more errors than healthy controls at T-pre regarding the total number of trials ($t(63) = -2.35$, $p = .022$, medium effect size) and the trials with many dots specifically ($t(63) = -2.43$, $p = .018$, medium effect size). At T-post, this difference was still present for the total number of trials ($t(63) = -2.12$, $p = .038$, medium effect size), while the difference for the trials with many dots was still of medium size, but just missed significance ($t(63) = -2.00$, $p = .050$). For the trials with few dots, no differences were found between the two groups for T-pre or T-post (both $p > .100$ and small effect sizes). No changes were found between T-pre and T-post for the accuracy scores on the dot counting task (all $p > .100$ and of negligible size).

For the accuracy rates of the visual search tests, no between-group or within-group effects were found (all $p > .100$, all small or negligible effect sizes, except for a medium sized difference between patients and healthy controls at T-post for the total number of errors on the serial search test).

Hazard perception test
No significant between-group or within-group effects were found for the accuracy rates of the hazard perception test (all $p > .100$, all small or negligible effect sizes).

Tracking Task
Data from the tracking task showed that after training, the number of omissions of peripheral stimuli had decreased significantly ($t(41) = 2.06$, $p = .046$, small effect size). Patients made more omissions than healthy controls, but this difference was of small size and not significant at T-pre ($t(44.2) = -2.00$, $p = .052$) and of negligible size and not significant at T-post ($p > .100$). No significant between-group or within-group effects were found for the number of incorrect responses (negligible effect sizes) and SDLP (small between-group differences and a negligible

within-group difference; all $p > .100$).

Reaction times for the peripheral stimuli are presented in Figure 7.1 and Figure 7.2. Detection of peripheral targets became faster between T-pre and T-post in the patient group ($t(40) = 2.28$, $p = .028$, small effect size), although the patients responded significantly slower than healthy controls at both T-pre ($t(63.6) = -5.42$, $p < .001$, large effect size) and T-post ($t(64) = -3.71$, $p < .001$, large effect size). A decrease in reaction time between T-pre and T-post was found especially for targets on the blind side ($t(40) = 3.06$, $p = .004$, small effect size) and not for targets on the seeing side ($p > .100$, negligible effect size). The difference in reaction times for stimuli on the blind and seeing side decreased after training ($t(40) = 2.85$, $p = .007$, small effect size). The dual-to-single-task-ratio (DSR) also decreased after training ($t(39) = 3.02$, $p = .004$, small effect size) and was significantly higher in the patient group than in the healthy control group at T-pre ($t(61.1) = -6.09$, $p < .001$, large effect size) as well as T-post ($t(61.9) = -3.54$, $p = .001$, medium effect size). DSR decreased specifically for stimuli on the blind side ($t(39) = 2.67$, $p = .011$, small effect size). DSR for stimuli on the seeing side was already close to 1.00 at T-pre and did not change by training ($p > .100$, negligible effect size).

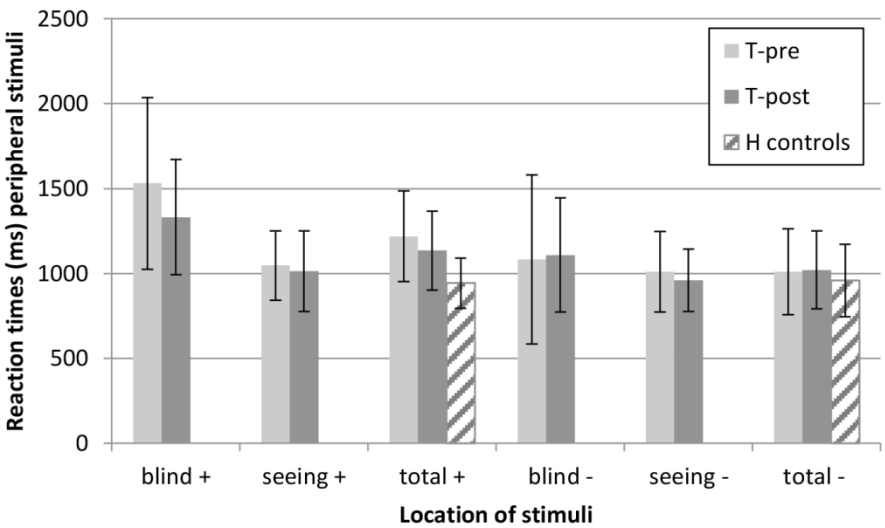


Figure 7.1. Reaction times (mean ± SD) for peripheral stimuli in the Tracking Task. Split for stimuli on the blind side and seeing side for the patient group. (+) dual task condition, (-) single task condition.

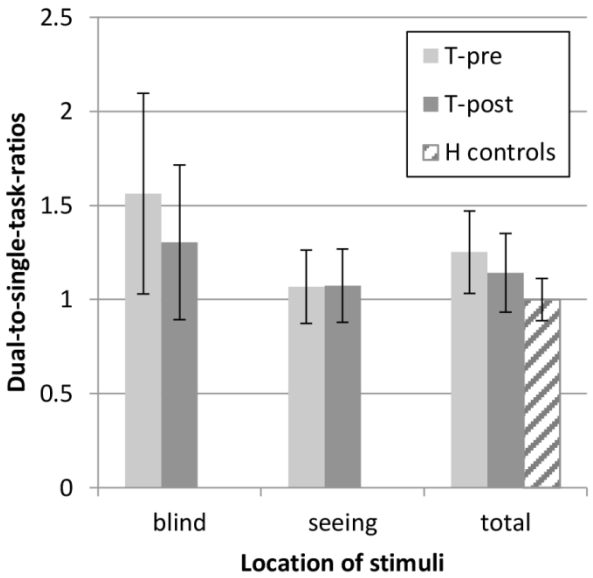


Figure 7.2. Dual-to-single-task-ratios (mean ± SD) for peripheral stimuli in the Tracking Task. Split for stimuli on the blind side and seeing side for the patient group.

Obstacle course

With regard to the obstacle course, the PPWS increased between T-pre and T-post ($t(42) = -2.21$, $p = .033$, small effect size). PPWS was significantly lower for patients than for healthy controls at both T-pre ($t(66) = -4.12$, $p < .001$, large effect size) and T-post ($t(66) = -3.32$, $p = .001$, medium effect size). The number of contacts was significantly higher for patients than for healthy controls at T-pre ($t(58.1) = 4.18$, $p < .001$, large effect size), decreased significantly between T-pre and T-post ($t(42) = 4.43$, $p < .001$, medium effect size) and was no longer significantly different between patients and healthy controls at T-post ($p > .100$, small effect size). Digit Score was significantly lower for patients than for healthy controls at T-pre ($t(66) = -2.21$, $p = .031$, medium effect size), but no longer at T-post ($p > .100$, small effect size), although change between T-pre and T-post was not significant ($p > .100$, small effect size).

Questionnaires

All three questionnaires indicated significant improvement between T-pre and T-post (all $p < .001$ and medium effect sizes).

Follow up

The questionnaire data are presented in Table 7.3 and Figure 7.3. For all three questionnaires, test scores changed significantly between T-pre, T-post, and FU ($F(2,41) = 20.25$, $p < .001$). Compared to T-pre, scores on all three questionnaires had significantly improved at the time of FU (all $p < .001$, medium effect sizes for IMQ and CVD, large effect size for VFQ). Between T-post and FU, the IMQ score and CVD score did not change significantly (both $p > .100$,

Table 7.3. Mean test scores (SD) and effect sizes for group differences (absolute values) for patients that completed follow-up (n = 43).

Questionnaires	T-pre	T-post	FU	Effect size T-pre vs. FU	Effect size T-post vs. FU
NEI-VFQ-25 total score	63.62 (13.78)	70.83 (11.30)	75.55 (12.25) a,b,c	0.98	0.53
IMQ total score	2.56 (0.70)	2.08 (0.52)	2.12 (0.54) a,b	0.68	0.08
CVD total score	0.47 (0.16)	0.36 (0.13)	0.37 (0.14) a,b	0.65	0.09

(a) significant overall effect of test assessment (GLM Repeated Measures, p-value < .001).
(b) significant difference between T-pre and FU (simple contrast, p-value < .001)
(c) significant difference between T-post and FU (simple contrast, p-value = .001)

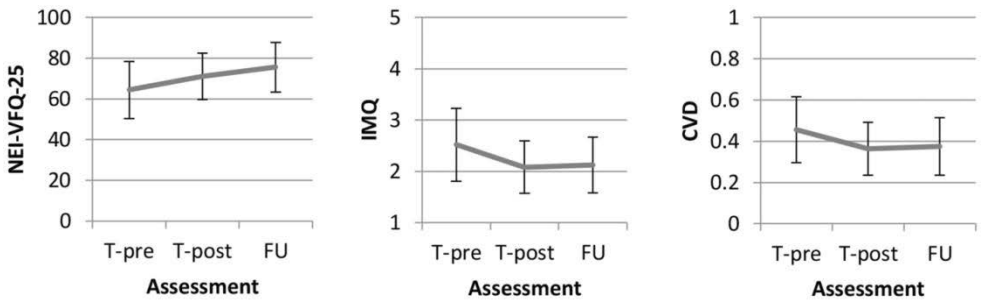


Figure 7.3. Questionnaire scores (mean and standard deviation presented) of the patient group on T-pre, T-post, and FU. Vertical axes indicate the mean total scores on the NEI-VFQ-25, the IMQ and the CVD.

negligible effect sizes), while the VFQ scores indicated further improvement ($F(1,42) = 12.27$, $p = .001$, medium effect size). Exclusion of the two patients with 11 and 15 months (instead of 6 to 10 months) between T-post and FU led to similar results (data not presented).

Self-reported performance related to test results

No significant correlations were found at T-pre between mobility performance in daily life as reported by the patients and mobility performance as measured in the Tracking Task and obstacle course ($r_{IMQ(pre)\ -\ TT\text{-}RT\text{-}all(pre)} = .158$, $p = .307$; $r_{IMQ(pre)\ -\ DSR\text{-}all(pre)} = .054$, $p = .732$; $r_{IMQ(pre)\ -\ PPWS(pre)} = -.013$, $p = .936$). Self-reported improvement in daily life mobility between T-pre and T-post was not found to be related to change in mobility performance on the Tracking Task or obstacle course ($r_{IMQ(diff)\ -\ TT\text{-}RT\text{-}all(diff)} = -.078$, $p = .628$; $r_{IMQ(diff)\ -\ DSR\text{-}all(diff)} = .067$, $p = .681$; $r_{IMQ(diff)\ -\ PPWS(diff)} = .018$, $p = .910$).

Predictors of training effects

The regression output in Table 7.4 shows the variables that were found to relate to the size of the training effects regarding the outcome measures IMQ, TT-RT-all, DSR-all and PPWS. Change between T-pre and T-post was mainly predicted by the scores on T-pre; patients performing worse on T-pre on average improved more than patients performing better on T-pre. For the reaction times to peripheral stimuli in de Tracking Task (TT-RT-all), it was found that besides the score on T-pre, side of the HVFD was also related to the extent of improvement. Reaction

Table 7.4. Results of regression analyses on potential predictors of training effects.

Training effect (T-pre - T-post)	Significant predictors	b	*p*-value	Regression formula
IMQ total score	IMQ_{pre}	0.577	<.001	IMQ_{diff} = -1.017 + 0.577 * IMQ_{pre}
TT-RT-all	TT-RT-all_{pre}	0.547	<.001	TT-RT-all_{diff} = -540.199 + 0.547 * TT-RT-all_{pre} –
	SideHH	-131.880	.037	131.880 * SideHH
DSR-all	DSR-all_{pre}	0.597	<.001	DSR-all_{diff} = -0.637 + 0.597 * DSR-all_{pre}
PPWS	$PPWS_{pre}$	0.331	.001	$PPWS_{diff}$ = -18.336 +0.331*$PPWS_{pre}$

Inserted as independent variables: score at T-pre, age, gender, side of HVFD, type of HVFD (hemianopia or quadrantanopia), Functional Field Size, time since onset, Mini Mental State Examination (total score) (Folstein et al., 1975), Trailmaking Test (TMT-A time, TMT-B time, B/A-index) (Reitan, 1958), Complex Figure of Rey (score on copy task) (Meyers & Meyers, 1995), Hospital Anxiety and Depression Scale (total score) (Spinhoven et al., 1997), Nederlandse Leestest voor Volwassenen ('ruwe score') (Schmand et al., 1992), 15 Word Test (total correct responses immediate recall, correct responses delayed recall) (Saan & Deelman, 1986; Van der Elst et al., 2005), Digit Span (maximum repeated numbers forward, maximum repeated numbers backward) (Wechsler, 1997)

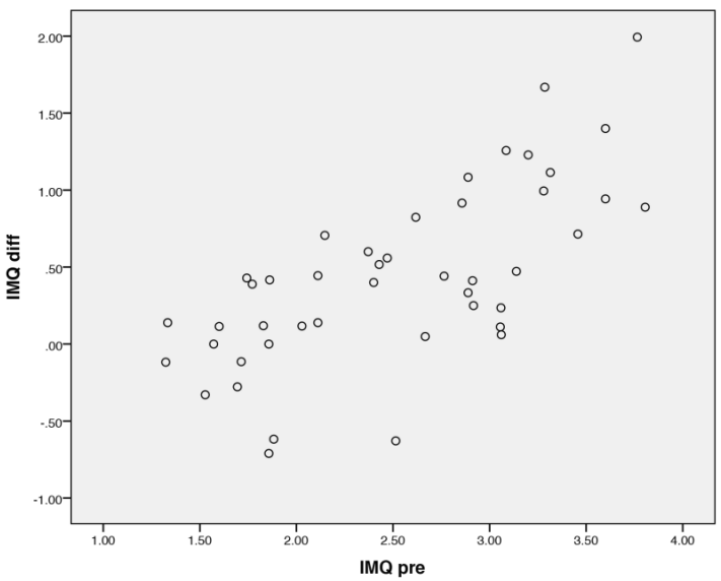


Figure 7.4. IMQ total score at T-pre (IMQ pre) vs. difference score (IMQ diff = T-pre – T-post: positive value means improvement).

times decreased more for patients with left-sided HVFD than for patients with right-sided HVFD. No other variables were found to be significant predictors in the regression models. Although the plots in Figure 7.4 to Figure 7.7 show that for every outcome parameter there were a few people who performed worse at T-post than at T-pre, there were no T-pre values for which all participants showed a decline in performance.

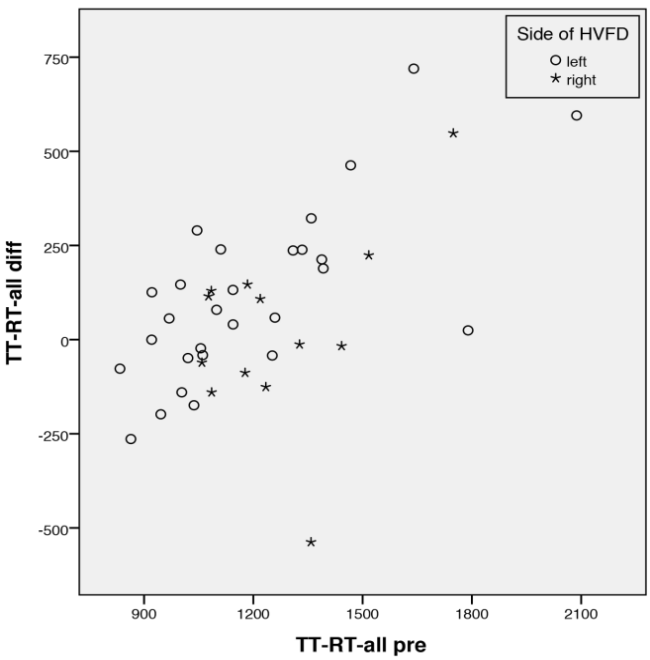


Figure 7.5. Reaction times to peripheral stimuli in the dual Tracking Task: score at T-pre (TT-RT-all pre) vs. difference score (TT-RT-all diff = T-pre – T-post: positive value means improvement).

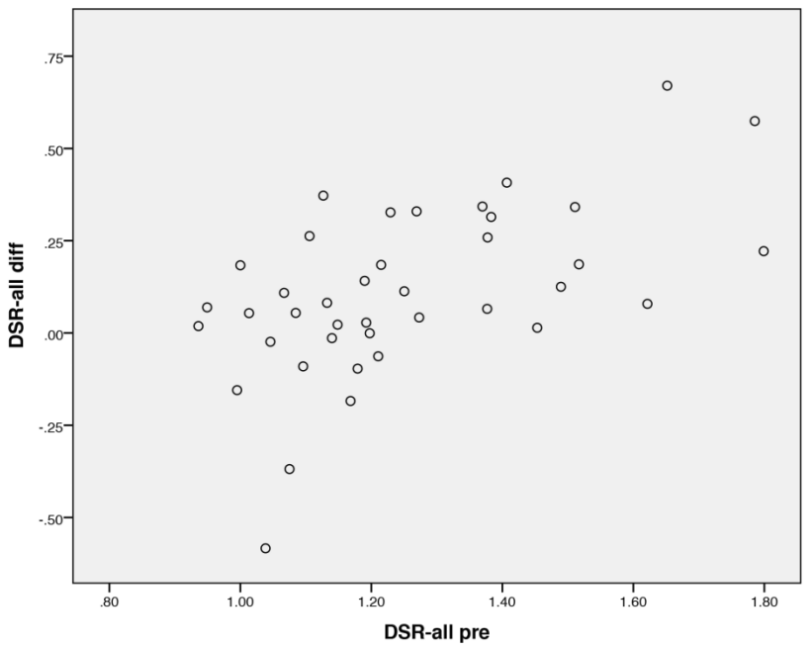


Figure 7.6. Dual-to-single-task-ratio in reaction times to peripheral stimuli in the dual Tracking Task: score at T-pre (DSR-all pre) vs. difference score (DSR-all diff = T-pre – T-post: positive value means improvement).

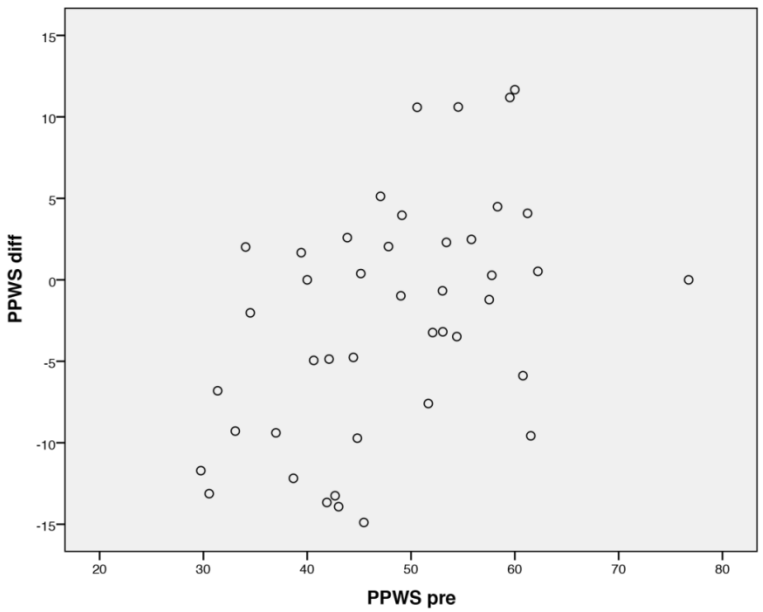


Figure 7.7. Percentage preferred walking speed in obstacle course cognitive dual task: score at T-pre (PPWS pre) vs. difference score (PPWS diff = T-pre – T-post: negative value means improvement).

DISCUSSION

This study evaluated the effects of compensatory scanning training (IH-CST) for patients with HVFD. First, it was examined whether the results of an RCT on the effect of IH-CST (chapter 6) could be confirmed in a larger patient sample by comparing data from T-pre and T-post and by comparing the patient group with a healthy control group. Second, it was evaluated whether there is evidence for long-term training effects. The third aim of this study was to determine whether training effects could be predicted by demographic characteristics, variables related to the patients' visual disorder, and neuropsychological test results. This would allow clinicians working in the field of rehabilitation to select appropriate and effective rehabilitation programs for their patients.

The results of the RCT (chapter 6, Appendix 7.1) showed that compared to a waiting list control group, patients who received the IH-CST specifically improved in detecting peripheral stimuli in mobility situations, while no effects were found on visual functions (including visual field size), reading, visual search or dot counting. Analyzing the data from T-pre and T-post in an extended patient group (which was created by merging the data of the training group and the waiting list control group of our previous report) provided further support for these conclusions. The within-group training effects in the current study were very similar to the within-group training effects in the training group of the previously reported RCT. However, the analysis of the current data revealed significant improvements in three parameters of the Tracking Task that were not found to be significant in a smaller sample, i.e. number of omissions of peripheral stimuli, reaction times for stimuli on the blind side, and difference in reaction times between the blind and seeing side. These differences are likely to be the result

of an enlarged power in the current analyses resulting from the larger sample size. Furthermore, a larger improvement on these parameters between T-pre and T-post was found in the subgroup that was added in the current analysis (i.e., the waiting list control group of the RCT) compared to the training group of the RCT. During the time the waiting list control group had to wait to access training, the performance in terms of these Tracking Task parameters deteriorated but, after following the training program, performance improved more than for the patients in the training group. The finding of the RCT that the number of correct answers on the standardized reading test increased significantly after training was not confirmed by the current analysis. Performance of the waiting list control group deteriorated slightly after patients had followed the training, decreasing the overall training effect of the full patient group. Regarding differences of effect sizes of the within-group training effects (in terms of effects of smaller or larger than 0.50), only one difference was found between the RCT analysis and the current analysis. A medium effect of 0.70 was found for the improvement in dual-to-single-task-ratio (DSR-all) in the RCT, while this effect just missed the threshold value for a medium effect in the current analysis (effect size 0.048). This difference can be explained by a smaller improvement between T-pre and T-post in the waiting list control group compared to the training group. During their time on the waiting list, the DSR-all of these patients on average deteriorated and following the training, their performance improved, but not as much as in the other patient group.

The improvements caused by training appear to be long-term effects. Based on the questionnaire data from the half year follow-up, the positive effects of training on activities and participation in daily life were still present or increased even further six months after training. However, the data also indicated that self-reported improvement did not correlate with improvement in objective mobility performance. Therefore, no conclusions can be drawn on the objective long-term training effects. Since the focus of the IH-CST is on automatizing the compensatory scanning strategy as much as possible, this skill might slowly deteriorate without the patient noticing. Therefore, one may consider implementing refresher sessions, e.g. six months following the training sessions and each following year.

In the present study, only patients without severe (neuro)psychological disorders, such as neglect, or psychiatric conditions, such as anxiety disorders, were included. In this group with minimal comorbidity, training effects could not be predicted by demographic characteristics, variables related to the visual disorder, or neuropsychological test results. The only variable with potential predictive value was *side of HVFD*, and by this *side of lesion*; reaction times to peripheral stimuli in a dual task situation decreased on average more for patients with a left-sided HVFD compared to patients with a right-sided HVFD. A recurring finding for both the subjective and the objective measures was that change between T-pre and T-post depended on performance at T-pre. Patients who performed worse before onset of training, showed in general more improvement after training, which might be explained by a ceiling effect for those patients that already performed well prior to training. However, even the patient group with the best performance before onset of training still improved on one or more parameters. It is hypothesized that the larger effect of training for lower performers has its limits. Patients with extremely low performance because of serious comorbidity, such as a severe cognitive or physical disorder, will presumably not be able to benefit from training. However, milder forms

of comorbidity should not be a reason to deny patients the IH-CST. The IH-CST might improve detection for peripheral stimuli, as was found for patients with only HVFD, in patients with neglect as well (with or without HVFD), depending on the nature and severity of the neglect. In general, the training effects are expected to be smaller for patients with neglect, since they usually have difficulty generalizing a learned skill to other activities and situations. Patients with mild neglect might benefit from additional training sessions to improve just as much as patients with only HVFD, while for patients with severe neglect, training might be aborted at some point in case no further progression is made. Further research is needed to examine the effects of IH-CST for patients with neglect.

Although the IH-CST improved visual performance in mobility-related tests, the patient group still performed poorer on most parameters after following the training in comparison to the healthy control group. Performance in the obstacle course after training, however, was no longer significantly different from the performance of the healthy control group after training regarding the number of contacts with obstacles and the score acquired in the cognitive task during walking. Ten out of 45 patients had not completed the training program at the time of T-post, i.e. these patients needed more than 15 sessions to complete the program. Therefore, the current results may have underestimated the effects of the full training program for some individuals.

With regard to clinical practice, the IH-CST is recommended for improving detection of visual stimuli during mobility-related activities for patients with HVFD and minimal comorbidity, as assessed via neuropsychological testing. An observation of visual performance during mobility-related activities prior to training seems crucial to inform the clinician and patient about the training effects to be expected. In order to evaluate the progress made by an individual patient, it is important to assess both the training effects as experienced by the patient, as well as the changes on objective test measures. The training protocol provides standardized exercises and scoring forms for the occupational therapists to measure progress, as well as an evaluation form that is used to assess the patients' own idea of improvement. In order to measure the objective improvement on mobility-related activities different from the exercises included in the training program, tests may be implemented in the rehabilitation center before and after training, such as a test similar to the Tracking Task of the current study. Standardized questionnaires, such as the IMQ, might be incorporated to quantify the changes as experienced by the patients.

In conclusion, additional evidence was provided confirming the beneficial effect of IH-CST on detection of visual stimuli during mobility-related activities. Again, no evidence was found for improvement on visual functions, reading, visual search and dot counting. According to the patients' reports, the effects were still present six to ten months after training. However, the patients' impressions could not be supported by objective data since no objective measurements were included in the follow-up assessment. Besides some evidence for more improvement in patients with a left-sided HVFD than in patients with right-sided HFVD, no demographic characteristics, variables related to the patients' visual disorders, and neuropsychological test results have been found to predict size of training effect in this sample where serious (neuro)psychological disorders have been excluded. Further research is needed to explore the effects and feasibility of IH-CST for patients with comorbidity and for children.

Also, it is recommended to examine the need for a follow-up training to ensure permanent use of the skills practiced and acquired during the IH-CST.

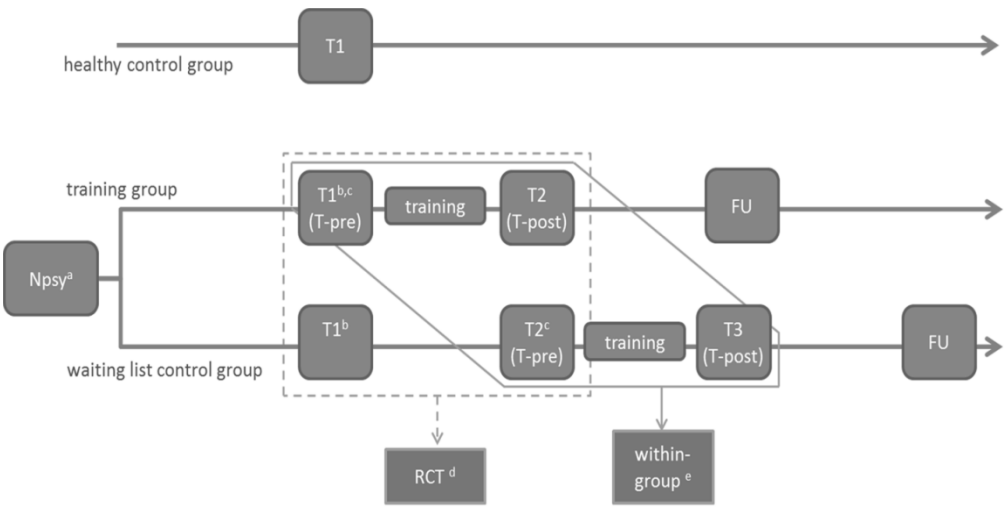
SUPPORTING INFORMATION

Individual-level data are available on request to author.

Acknowledgments

Special thanks goes out to all participants, as well as the staff from Royal Dutch Visio and Bartiméus involved in participant recruitment and training. The authors gratefully acknowledge dr. Casper Albers of the Department Psychometrics & Statistics at the University of Groningen, the Netherlands, for his advice on the statistics.

APPENDIX 7.1: FULL STUDY DESIGN



[a] Neuropsychological testing in the inclusion phase including Mini Mental State Examination (Folstein et al., 1975), Trailmaking Test (Reitan, 1958), Complex Figure of Rey (Meyers & Meyers, 1995), and Hospital Anxiety and Depression Scale (Spinhoven et al., 1997);

[b] including the neuropsychological tests Nederlandse Leestest voor Volwassenen (Schmand et al., 1992) and 15 Word Test (Saan & Deelman, 1986; Van der Elst et al., 2005);

[c] including the neuropsychological test Digit Span (subtest of the WAIS) (Wechsler, 1997);

[d] treatment - non-treatment comparison (RCT; chapter 6);

[e] within-group comparison of training effect (analysis described in the present paper); FU = follow up.

8

General discussion and conclusion

The present thesis focused on the consequences of having a homonymous visual field defect (HVFD) for daily living, and more specifically, for mobility-related activities and participation. Four important issues were addressed: the focus of previous studies on HVFD, the functioning of patients with HVFD, the effects of training, and the factors that influence functioning or training effects. This final chapter reflects on these four issues based on the results of the systematic review of the literature on HVFD and the randomized controlled trial (RCT) on the effects of training. The preceding chapters each discussed the strengths and limitations of the individual studies. This last chapter will focus on the implications for clinical practice and suggestions for future research.

FOCUS OF PREVIOUS RESEARCH

Previous reviews on HVFD (Bouwmeester et al., 2007; Kerkhoff, 1999; Pollock et al., 2011) indicated that knowledge about the effects of training on mobility in daily life was missing, which was one of the reasons to perform the present study. Our systematic review of 221 papers on HVFD (see **chapter 3**) not only confirmed this previously reported lack of outcome measures within the domain of mobility-related activities and participation, but also showed that activities and participation in general were examined in only a marginal portion of the studies. Previous studies predominantly focused on body functions, such as lesion location, etiology, visual functions, and neuropsychological functions. The scientific findings of these studies are therefore hard to relate to the impact of having HVFD on functioning in daily life. There appears to be a discrepancy between the outcome of scientific research on HVFD and the implications for clinical practice. While the main goal of rehabilitation is usually to improve activities and participation in daily life, few scientific studies have been performed examining the effects of rehabilitation on activities and participation. Although ecologically valid measures on the level of activity and participation may face standardization issues, our study shows that it is possible to include measures that are standardized, as well as ecologically valid. In conclusion, previous research provided valuable insight, however, our knowledge about the difficulties experienced by patients with HVFD in daily life that should be targeted by rehabilitation programs is insufficient. It is unknown which rehabilitation programs effectively improve functioning in everyday life.

IMPACT OF HVFD ON FUNCTIONING IN DAILY LIFE

We performed the first systematic inventory of the difficulties patients with HVFD and minimal comorbidities report to experience in daily life (see **chapter 4**). This inventory confirmed that HVFD often leads to difficulties with reading, orientation, and mobility-related activities. Surprisingly, a number of problems were frequently reported that did not seem directly related to missing portions of the visual field and that have not been related to HVFD before. These problems included disturbed light sensitivity, color perception, and depth perception and could represent additional consequences of the brain damage. Based on these findings, further research on the complaints of HVFD patients has been initiated (funded by ZonMw-InZicht: project 94310003). Other frequently reported difficulties were related to recreation and leisure activities, negative feelings and thoughts, and feelings of decreased independence. These complaints once more stress the need for effective rehabilitation programs.

The influence of HVFD on mobility was objectified by comparing performance of patients with HVFD on mobility-related tests with performance of a healthy control group (see **chapter 6 and 7**). The results suggest that patients with HVFD need significantly more time to detect peripheral stimuli and have more difficulty to avoid obstacles while walking, especially when performing a secondary task simultaneously. These difficulties were not significantly related to the mobility impairments experienced in daily life as reported by patients. This implies that reports of the patients do not necessarily reflect their actual level of performance.

An activity significantly contributing to independent mobility is car driving. We performed a study on driving performance in a group of 26 patients with HVFD and minimal comorbidities (see **chapter 5**). It was found that spontaneous compensation for the HVFD while driving a car was insufficient for 12 participants. Not only impairments in viewing behavior, but also in tactical and operational aspects of driving were observed. Possibly, spontaneous attempts to compensate for the HVFD limited available attentional capacities, resulting in impairments in tactical and operational aspects of driving. Aspects of driving that were most frequently reported not to be sufficient were steering stability, speed adaptation, and anticipating environmental changes while applying compensatory scanning behavior simultaneously. The results also indicated, however, that part of the patients with HVFD were able to compensate for the HVFD effectively and were judged to be fit to drive. This illustrates the wide variance in driving performance among patients with HVFD. It can be concluded that decisions on practical fitness to drive cannot be solely based on visual field size.

EFFECTS OF IH-CST

The effects of the newly developed InSight-Hemianopia Compensatory Scanning Training (IH-CST) were investigated in an RCT (see **chapter 6 and 7**). This was the first RCT to find specific effects of a compensatory scanning training (CST) on mobility-related activities and participation. Especially detection of peripheral stimuli in mobility situations improved, while simultaneously performed tasks were not affected, or even improved as well. This suggests that compensatory scanning was automatized to a significant degree. This is an important finding, since most mobility-related activities are dual task activities (e.g., having a conversation while walking). Furthermore, it is important that sufficient attentional capacity remains available for reacting on unexpected events, such as unanticipated actions from other road-users. The results indicate that IH-CST does not lead to overcompensation. Detection of stimuli in the blind periphery became faster, while reaction times to stimuli in the seeing periphery did not change. Based on the reports of the participants, the positive effects of the IH-CST were still present six to ten months after training. No conclusions could be drawn on the long term effects of training on mobility-related performance, since no objective test was included in the follow-up and because improvements in performance on mobility-related tests could not be predicted by self-reported improvement in daily life mobility. No evidence was found for an effect of IH-CST on visual functions (e.g., visual field size), nor on reading or visual search. The lack of effects on reading and visual search suggests that different scanning strategies are helpful for different types of activities. Detecting peripheral stimuli, which is important during mobility-related activities, was found to improve after practicing the wide, horizontal scanning strategy from the IH-CST. Searching for a specific target among distracting

information, important when looking for a specific product on a shelf for example, did not improve and appears to require a different type of scanning. This is in line with findings of previous studies suggesting that the effects of CST are specific and task-dependent (Aimola et al., 2014; Hardiess et al., 2010; Schuett et al., 2012).

PREDICTORS OF FUNCTIONING AND SUCCESS OF TRAINING

From a rehabilitation perspective, it is important to know which factors predict the level of functioning that a patient will reach and which factors predict the effects of training. This knowledge may guide professionals in providing the best intervention for each individual patient with HVFD. According to the review of 221 papers on HVFD (see **chapter 3**), the existing literature provides insufficient information on potential predictors of future functioning of the patient or the effects of specific training programs. Previous studies mainly focused on the predictive value of body functions (e.g., visual field size) or personal factors (e.g., age) on body functions (e.g., recovery of visual field) or, less often, on activities (e.g., reading speed). There were no reports about potential predictors of the effects of compensatory training on participation in society.

In the studies described in this thesis, we examined the predictive value of a number of variables on the difficulties experienced by HVFD patients in daily life (see **chapter 4**) and on their on-road car driving performance (see **chapter 5**). In addition, it was examined which variables could predict the effects of the IH-CST program (see **chapter 7**). We found that younger participants reported a wider range of activities as being difficult because of the HVFD. Younger participants were also less satisfied with their ability to travel independently than older participants. Furthermore, women experienced difficulties in a wider range of activities than men. It could be that younger and female patients performed a broader range of activities before the onset of the HVFD, resulting in a more extensive impact of the HVFD. Age and gender were not found to be related to car driving performance. Significant associations were found between driving performance and time not having driven a car, visual field size, and side of field defect. Visual scanning and operational handling of the car were found to be more impaired with longer time not driven. A larger intact visual field was related to better driving performance. However, no cut-off point for visual field size was found below which all participants were unfit to drive. Patients with right-sided HVFD on average performed better on the driving test then left-sided HVFD patients, but these results have to be interpreted with caution because of the different sample sizes of the two groups.

With regard to the effects of IH-CST on mobility-related activities and participation, some evidence was found for more improvement in patients with left-sided HVFD as compared to patients with right-sided HVFD, although this was not found for all tests analyzed. No evidence was found for an influence of age, gender, visual field size, time since onset of the HVFD, or neuropsychological test performance on the effects of IH-CST. The main predictor of the effect of training was found to be the level of performance before onset of training. Patients performing worse before training on average improved more than patients that performed better before training. However, even patients with the highest level of performance before onset of training showed improvements.

In conclusion, the impact of HVFD on daily life or the effects of IH-CST cannot be predicted

by demographic characteristics, variables related to the visual disorder, or neuropsychological test results at this point. Presumably, many factors, including personality traits and support from family and friends, together determine the impact of HVFD or the effect of training.

RECOMMENDATIONS FOR CLINICAL PRACTICE AND FUTURE RESEARCH

As a result of the current study, an evidence-based protocolled CST program for improving orientation and mobility in daily life is now available for patients with HVFD. Because the study was so closely linked to the clinical setting, the recommendations can easily be applied to clinical practice. A report resulting from this study has led to further implementation of the IH-CST in additional locations of Visio and Bartiméus specialized in visual rehabilitation in the Netherlands. International interest has started preparations for implementation of the IH-CST in other countries. Besides translation of all training materials, other adaptations are possibly necessary in order to fit the IH-CST to traffic situations abroad. Cycling exercises, for example, might be excluded from the protocol in countries where bicycles are rarely used.

Based on the results described in this thesis, the IH-CST is recommended for improving detection of peripheral visual stimuli during mobility-related activities in patients with HVFD. Other types of activities, such as reading and visual search tasks, appear to require different types of compensatory scanning. In case the HVFD leads to difficulties with multiple types of activities, the different types of compensatory scanning strategies are preferably not trained simultaneously, but sequentially. Automatizing a scanning strategy as much as possible before learning a second scanning strategy, minimizes cognitive demands. At this point, there is no evidence for a preferred order in learning different scanning strategies. Possibly, additional training is helpful for learning to alternate, combine, or integrate the different scanning strategies.

Before onset of the IH-CST, it is advisable to examine both the mobility-related difficulties experienced by the patient, as well as actual performance during mobility-related activities. This information not only directs the content of the training program, but also predicts the effect of training. Patients with a better level of performance before onset of training are expected to improve less, although this improvement may still make a great difference in daily life. Assessing the effect of training on both subjective and objective measures is recommended, since both are important but were not found to be related. The protocol provides an evaluation form for registering the changes as experienced by the patient. Quantifying patients' own idea of improvement may be achieved by incorporating a standardized questionnaire, e.g. the IMQ (described in **chapter 4**). Standardized exercises and scoring forms for measuring progress in performance are included in the protocol. In order to measure the improvement in performance on mobility-related activities different from the exercises from the training program, other tests may be implemented in the rehabilitation center before and after training, e.g. a test similar to the Tracking Task (described in **chapter 6**).

The current version of the IH-CST is now evidence-based. This does not preclude that the protocol could possibly be further improved, keeping in mind that changes to the program may lead to an increase or decrease of its effectiveness and require new effect studies. Future research could examine to what degree the following characteristics of the current program contribute to the improvements in mobility-related activities and participation: exercises for

increasing awareness and insight, exercises for practicing the scanning strategy, exercises for practicing the strategy in daily life situations, characteristics of the scanning strategy (top-down systematic strategy with large horizontal saccades), face-to-face training, therapists' feedback, and homework assignments. Some exercises might be more effective than others, with some possibly being even redundant. This may depend on characteristics and treatment goals of the individual patient. Questionnaire data of the patients and occupational therapists on the feasibility of the training, as well as the session reports on the progress of the patients, have not been described in the current thesis, but are an important source of information on the value of the different training elements. Most exercises in the IH-CST program are focused on practicing the horizontal scanning rhythm and our results suggest that this leads to an improvement in visual performance during mobility-related activities, but not during visual search tasks. Future analyses of the eye tracking data might indicate to what extent participants applied the horizontal scanning strategy during the visual search tests, how eye movements changed after training, and which scanning strategies were related to better performance in terms of accuracy and speed. Eye tracking during the mobility-related activities was not performed in the current study, but is important for conclusions on the importance of the horizontal scanning strategy. If it is objectified that the horizontal scanning rhythm is indeed applied during mobility-related activities after training and that this application is related to better performance, further support for the positive effects of this specific scanning rhythm would be provided. Although the current findings do not suggest that patients with quadrantanopia benefit less from the IH-CST, it might be found that these patients apply slightly different scan patterns and that an adapted version of the scanning strategy is actually more efficient (e.g., including a large saccade towards the upper or lower corner of the affected quadrant instead of a large saccade towards the horizontal left or right). Another suggestion for future research is to examine the need for implementing a short refresher course a couple of months after completion of the training.

Alongside the attempts to improve the IH-CST for patients comparable to the participants in the current study, future research is needed to examine the effects of the IH-CST or an adapted version for patients with comorbidity. Until further research has shown which training components are most effective, it is recommended to maintain the three main elements of the program, i.e. exercises for improving awareness and insight, exercises for practicing a scanning strategy, and exercises aimed at transfer to daily life. The nature of these exercises may be adjusted for specific patient groups, which requires further research. For example, children with HVFD may need easier and more attractive exercises. Patients with neglect may benefit from additional exercises aimed at transfer to daily activities, depending on the severity of the neglect. For patients with other types of visual field defects, e.g. because of prechiasmatic or ocular diseases, a different scanning strategy could be implemented in the program.

The results from the on-road driving tests provided information on the problems encountered during driving. These findings suggest that training programs aimed at improving practical fitness to drive in people with HVFD should include both visual scanning training, as well as driving lessons (on-road or in a simulator) to improve driving skills such as steering stability, speed adaptation, and anticipating environmental changes while applying compensatory scanning behavior simultaneously. The IH-CST appears to be a suitable training

to include in the training of car driving performance for HVFD patients, since the IH-CST has been found to improve visual performance in mobility-related activities mainly in dual tasks, which car driving certainly is. Further analysis of the on-road driving tests after IH-CST followed by driving lessons is recommended in order to examine the effects of training on car driving. Data from the questionnaire on car driving administered at our follow-up assessment may provide insight in the effects on car driving as experienced by the patients. Analyses of the simulated driving tests performed at T2 might provide information on the changes in car driving performance that can be attributed to IH-CST alone, i.e. changes that cannot be attributed to the driving lessons. The associations between on-road driving performance, simulated driving performance, and performance on other tests (such as the Tracking Task or Hazard perception test) could indicate whether on-road driving performance can be predicted by off-road testing. These associations could be further examined in a group of patients not ready for an on-road driving test because of physical or cognitive comorbidity or because they do not trust themselves on the road yet. If an off-road test is found to be highly correlated with on-road driving performance, this test could possibly be incorporated in the relicensure procedure in order to examine if a patient is ready for the on-road driving test. Within the range of visual field sizes in our study, we have not found a minimal visual field size needed for safe driving. A HVFD does not necessarily lead to impaired driving performance. Policy makers could therefore reconsider the visual field size required for participation in a test of practical fitness to drive.

Besides recommendations regarding the IH-CST and the assessment and training of driving performance, some recommendations are provided related to examining the consequences of the HVFD. When questioning the patient about the difficulties he or she experiences, it is advised to start with open-ended questions. After that, difficulties known to occur frequently can be presented to the patient, e.g. using standardized questionnaires. Especially, more attention should be paid to disorders of light sensitivity, color perception, and depth perception in clinical assessments of patients with HVFD. It is recommended to assess both difficulties experienced by the patients in daily life, as well as actual performance on mobility-related activities. Both types of measures are relevant, but the information they provide is different, as illustrated by the low correlations in our study.

Our last recommendation is related to the International Classification of Functioning, Disability, and Health (ICF). The ICF has been used repeatedly throughout this study. We found that the ICF helps to clarify the scope of literature (see **chapter 3)**, instruments (e.g., questionnaires, see **chapter 4**), difficulties in daily life (see **chapter 4**) and training programs (see **chapter 6**). Greater convergence between problems experienced by patients in everyday life, rehabilitation programs, and scientific research can be reached, when they focus on the same variables. It is therefore recommended to be aware of and report on the specific body functions, activities, personal factors, etc. when designing a rehabilitation program or when evaluating the effects of rehabilitation programs. For this aim, the ICF can be a valuable starting point, supplemented with specific parameters if necessary. Specifying the ICF domains in the literature on HFVDs showed that more research is needed on the activities and participation domains in order to bridge the gap between research and clinical practice.

CONCLUSION

The studies described in this thesis have contributed to our knowledge on the consequences of having HVFD for everyday life, and more specifically, for mobility-related activities and participation. Our systematic review on 221 papers resulted in an overview of the literature on HVFD. This overview may be used as a reference work or as a starting point for further literature search. The RCT resulted in an overview of the difficulties patients experience in daily life, in knowledge about the impact of HVFD on car driving, and in an evidence-based training protocol for improving mobility-related activities and participation in patients with HVFD. These results have led to recommendations for clinical practice. This thesis hopefully contributes to more effective assessments and rehabilitation programs for people with HVFD, with the ultimate goal of improving mobility-related activities, participation in society and quality of life.

References

Aimola, L., Lane, A. R., Smith, D. T., Kerkhoff, G., Ford, G. A., & Schenk, T. (2014). Efficacy and Feasibility of Home-Based Training for Individuals With Homonymous Visual Field Defects. *Neurorehabilitation and Neural Repair, 28*(3), 207-218.

Alexander, I., & Cowey, A. (2009). The cortical basis of global motion detection in blindsight. *Experimental Brain Research, 192*(3), 407-411.

Ali, M., Hazelton, C., Lyden, P., Pollock, A., Brady, M., & VISTA Collaboration. (2013). Recovery From Poststroke Visual Impairment: Evidence From a Clinical Trials Resource. *Neurorehabilitation and Neural Repair, 27*(2), 133-141.

American Medical Association. (2008). The visual system. In R. D. Rondinelli, E. Genovese, R. T. Katz, T. G. Mayer, K. L. Mueller, M. I. Ranavaya & C. R. Brigham (Eds.), *Guides to the Evaluation of Permanent Impairment* (6th ed., pp. 281-319). Chicago: American Medical Association.

Bahnemann, M., Hamel, J., De Beukelaer, S., Ohl, S., Kehrer, S., Audebert, H., . . . Brandt, S. A. (2015). Compensatory eye and head movements of patients with homonymous hemianopia in the naturalistic setting of a driving simulation. *Journal of Neurology, 262*(2), 316-325.

Baraldi, A. N., & Enders, C. K. (2010). An introduction to modern missing data analyses. *Journal of School Psychology, 48*(1), 5-37.

Barton, J. J. S., Behrmann, M., & Black, S. (1998). Ocular search during line bisection - The effects of hemi-neglect and hemianopia. *Brain, 121*, 1117-1131.

Barton, J. J. S., & Black, S. E. (1998). Line bisection in hemianopia. *Journal of Neurology Neurosurgery and Psychiatry, 64*(5), 660-662.

Barton, J. J. S., & Sharpe, J. A. (1997). Motion direction discrimination in blind hemifields. *Annals of Neurology, 41*(2), 255-264.

Beal, M. F., & Chapman, P. H. (1980). Cortical Blindness and Homonymous Hemianopia in the Postpartum Period. *Jama-Journal of the American Medical Association, 244*(18), 2085-2087.

Bergsma, D. P., & Van der Wildt, G. (2010). Visual training of cerebral blindness patients gradually enlarges the visual field. *British Journal of Ophthalmology, 94*(1), 88-96.

Bergsma, D. P., & Van der Wildt, G. J. (2008). Properties of the regained visual field after visual detection training of hemianopsia patients. *Restorative Neurology and Neuroscience, 26*(4-5), 365-375.

Biersdorf, W. R., Bell, R. A., & Beck, R. W. (1992). Pattern Flash Visual Evoked-Potentials in Patients with Homonymous Hemianopia. *Documenta Ophthalmologica, 80*(1), 51-61.

Blythe, I. M., Kennard, C., & Ruddock, K. H. (1987). Residual Vision in Patients with Retrogeniculate Lesions of the Visual Pathways. *Brain, 110*, 887-905.

Bolognini, N., Rasi, F., Coccia, M., & Ladavas, E. (2005). Visual search improvement in hemianopic patients after audio-visual stimulation. *Brain, 128*, 2830-2842.

Bouwmeester, L., Heutink, J., & Lucas, C. (2007). The effect of visual training for patients with visual field defects due to brain damage: a systematic review. *Journal of Neurology Neurosurgery and Psychiatry, 78*(6), 555-564.

Bowers, A. R., Keeney, K., & Peli, E. (2008). Community-based trial of a peripheral prism visual field expansion device for hemianopia. *Archives of Ophthalmology, 126*(5), 657-664.

Bowers, A. R., Mandel, A. J., Goldstein, R. B., & Peli, E. (2009). Driving with Hemianopia, I: Detection Performance in a Driving Simulator. *Investigative Ophthalmology & Visual Science, 50*(11), 5137-5147.

Bowers, A. R., Mandel, A. J., Goldstein, R. B., & Peli, E. (2010). Driving with Hemianopia, II: Lane Position and Steering in a Driving Simulator. *Investigative Ophthalmology & Visual Science, 51*(12), 6605-6613.

Brandt, T., Bucher, S. F., Seelos, K. C., & Dieterich, M. (1998). Bilateral functional MRI activation of the basal ganglia and middle temporal/medial superior temporal motion-sensitive areas - Optokinetic stimulation in homonymous hemianopia. *Archives of Neurology, 55*(8), 1126-1131.

Braun, C., Weber, J., Schiefer, U., Skalej, M., & Dietrich, T. (2001). Hyperexcitatory activity in visual cortex in homonymous hemianopia after stroke. *Clinical Neurophysiology, 112*(2), 336-343.

Bridge, H., Jindahra, P., Barbur, J., & Plant, G. T. (2011). Imaging Reveals Optic Tract Degeneration in Hemianopia. *Investigative Ophthalmology & Visual Science, 52*(1), 382-388.

Brigell, M. G., Celesia, G. G., Salvi, F., & Clarkbash, R. (1990). Topographic Mapping of Electrophysiologic Measures in Patients with Homonymous Hemianopia. *Neurology, 40*(10), 1566-1570.

Brouwer, W. H., Busscher, R. B., & Tant, M. L. (2013). On-Road Driving In Homonymous Hemianopia After Stroke: The Importance Of Attention And Perceptual Speed. In: Final Program The 2013 International Neuropsychological Society Mid–Year Meeting July 10–13, 2013. *J Int Neuropsychol Soc [Serial Online],* Amsterdam, The Netherlands*, 19*(S2) i-122.

Brouwer, W. H., Busscher, R. B., Davidse, R., Pot, H., & Van Wolffelaar, P. C. (2011). Traumatic brain injury: Tests in a driving simulator as part of the neuropsychological assessment of fitness to drive. In D. L. Fisher, M. Rizzo, J. K. Caird & J. D. Lee (Eds.), *Handbook of Driving Simulation for Engineering, Medicine and Psychology* (pp. 1-11)

Brouwer, W. H., & Ponds, R. W. H. M. (1994). Driving competence in older persons. *Disability and Rehabilitation, 16*(3), 149-161.

Brouwer, W. H., Withaar, F. K., Tant, M. L. M., & Van Zomeren, A. H. (2002). Attention and driving in traumatic brain injury: A question of coping with time-pressure. *Journal of Head Trauma Rehabilitation, 17*(1), 1-15.

Bruce, B. B., Zhang, X., Kedar, S., Newman, N. J., & Biousse, V. (2006). Traumatic homonymous hemianopia. *Journal of Neurology Neurosurgery and Psychiatry, 77*(8), 986-988.

Bruyere, S., Van Looy, S., & Peterson, D. (2005). The international classification of functioning, disability and health: Contemporary literature overview. *Rehabilitation Psychology, 50*(2), 113-121.

Butter, C. M., Kosslyn, S., MijovicPrelec, D., & Riffle, A. (1997). Field-specific deficits in visual imagery following hemianopia due to unilateral occipital infarcts. *Brain, 120*, 217-228.

Bynke, H. (1984). A Study of the Depth of Hemianopic Field Defects for Optimizing Computerized Perimetry. *Neuro-Ophthalmology, 4*(4), 237-247.

Cavezian, C., Gaudry, I., Perez, C., Coubard, O., Doucet, G., Peyrin, C., . . . Chokron, S. (2010). Specific impairments in visual processing following lesion side in hemianopic patients. *Cortex, 46*(9), 1123-1131.

Celesia, G. G., Brigell, M. G., & Vaphiades, M. S. (1997). Hemianopic anosognosia. *Neurology, 49*(1), 88-97.

Celesia, G. G., Meredith, J. T., & Pluff, K. (1983). Perimetry, Visual Evoked-Potentials and Visual Evoked Spectrum Array in Homonymous Hemianopia. *Electroencephalography and Clinical Neurophysiology, 56*(1), 16-30.

Cerniauskaite, M., Quintas, R., Boldt, C., Raggi, A., Cieza, A., Bickenbach, J. E., & Leonardi, M. (2011). Systematic literature review on ICF from 2001 to 2009: its use, implementation and operationalisation. *Disability and Rehabilitation, 33*(4), 281-309.

Chen, C. S., Lee, A. W., Clarke, G., Hayes, A., George, S., Vincent, R., . . . Crotty, M. (2009). Vision-Related Quality of Life in Patients with Complete Homonymous Hemianopia Post Stroke. *Topics in Stroke Rehabilitation, 16*(6), 445-453.

Chervinsky, A., Ommaya, A., deJonge, M., Spector, J., Schwab, K., & Salazar, A. (1998). Motivation for traumatic brain injury rehabilitation questionnaire (MOT-Q): Reliability, factor analysis, and relationship to MMPI-2 variables. *Archives of Clinical Neuropsychology, 13*(5), 433-446.

Chokron, S., Perez, C., Obadia, M., Gaudry, I., Laloum, L., & Gout, O. (2008). From blindsight to sight: Cognitive rehabilitation of visual field defects. *Restorative Neurology and Neuroscience, 26*(4-5), 305-320.

Cieza, A., Geyh, S., Chatterji, S., Kostanjsek, N., Ustun, B., & Stucki, G. (2005). Icf linking rules: An update based on lessons learned. *Journal of Rehabilitation Medicine, 37*(4), 212-218.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohn, R. (1972). Eyeball Movements in Homonymous Hemianopia Following Simultaneous Bitemporal Object Presentation. *Neurology, 22*(1), 12-14.

Corin, M. S., & Bender, M. B. (1972). Mislocalization in Visual Space - with Reference to Midline at Boundary of a Homonymous Hemianopia. *Archives of Neurology, 27*(3), 252-262.

Crevits, L., & Vanlith, G. H. M. (1983). Component Analysis of Pattern Evoked Occipital Potentials in Hemianopic Patients. *Documenta Ophthalmologica, 55*(4), 295-305.

Critchley, M. (1949). The problem of awareness or non-awareness of hemianopic field defects. *Transactions of the Ophthalmological Society UK, 69*, 95-109.

Crosson, B., Barco, P. P., Velozo, C. A., Bolesta, M. M., Cooper, P. V., Werts, D., & Brobeck, T. C. (1989). Awareness and compensation in postacute head injury rehabilitation. *Journal of Head Trauma Rehabilitation, 4*(3), 46-54.

Danckert, J., Revol, P., Pisella, L., Krolak-Salmon, P., Vighetto, A., Goodale, M. A., & Rossetti, Y. (2003). Measuring unconscious actions in action-blindsight: exploring the kinematics of pointing movements to targets in the blind field of two patients with cortical hemianopia. *Neuropsychologia, 41*(8), 1068-1081.

De Haan, G. A., Melis-Dankers, B. J., Brouwer, W. H., Tucha, O., & Heutink, J. (2015). The Effects of Compensatory Scanning Training on Mobility in Patients with Homonymous Visual Field Defects: A Randomized Controlled Trial. *PloS One, 10*(8), e0134459.

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Brouwer, W. H., & Tucha, O. (2015). Difficulties in daily life reported by patients with homonymous visual field defects. *Journal of Neuro-Ophthalmology, 35*, 259-264.

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Tucha, O., & Brouwer, W. H. (2014). Spontaneous recovery and treatment effects in patients with homonymous visual field defects: a meta-analysis of existing literature in terms of the ICF framework. *Survey of Ophthalmology, 59*(1), 77-96.

Dekeyser, M., Neetens, A., & Vissenberg, I. (1991). Objective Assessment and Detection of Hemianopia and Hemineglect with Visual Evoked-Potentials. *Neuro-Ophthalmology, 11*(1), 49-58.

Doehring, D. G., & Reitan, R. M. (1961a). Behavioral Consequences of Brain Damage Associated with Homonymous Visual Field Defects. *Journal of Comparative and Physiological Psychology, 54*(5), 489-492.

Doehring, D. G., & Reitan, R. M. (1961b). Language Disorders in Brain-Damaged Patients - Effects of Homonymous Visual Field Defects. *Archives of Neurology, 5*(3), 294-299.

Doehring, D. G., Reitan, R. M., & Klove, H. (1961). Changes in Patterns of Intelligence-Test Performance Associated with Homonymous Visual-Field Defects. *Journal of Nervous and Mental Disease, 132*(3), 227-233.

Doricchi, F., Onida, A., & Guariglia, P. (2002). Horizontal space misrepresentation in unilateral brain damage II. Eye-head centered modulation of visual misrepresentation in hemianopia without neglect. *Neuropsychologia, 40*(8), 1118-1128.

Dromerick, A. W., & Reding, M. J. (1995). Functional Outcome for Patients with Hemiparesis, Hemihypesthesia, and Hemianopia - does Lesion Location Matter. *Stroke, 26*(11), 2023-2026.

Duits, A., & Kessels, R. (2006). Schatten van het premorbide functioneren. In M. Hendriks, R. Kessels, M. Gorissen & B. Schmand (Eds.), *Neuropsychologische diagnostiek. De klinische praktijk.* (pp. 119-129). Amsterdam: Boom.

Edgeworth, J. A., Robertson, I. H., & McMillan, T. M. (1998). *The Balloons Test* Thames Valley Test Company.

Elgin, J., McGwin, G., Wood, J. M., Vaphiades, M. S., Braswell, R. A., DeCarlo, D. K., . . . Owsley, C. (2010). Evaluation of On-Road Driving in People With Hemianopia and Quadrantanopia. *American Journal of Occupational Therapy, 64*(2), 268-278.

Engler, U., Zihl, J., & Poppel, E. (1993). Incongruity of Homonymous Visual-Field Defects. *Clinical Vision Sciences, 8*(4), 355-363.

European Parliament, Council of the European Union. (2006). Directive 2006/126/EC of the European Parliament and of the Council of 20 December 2006 on driving licences (Recast). *Official Journal of the European Union, L403, 49*, 18-60.

Fayed, N., Cieza, A., & Bickenbach, J. E. (2011). Linking health and health-related information to the ICF: a systematic review of the literature from 2001 to 2008. *Disability and Rehabilitation, 33*(21-22), 1941-1951.

Feigenson, J. S., McCarthy, M. L., Greenberg, S. D., & Feigenson, W. D. (1977). Factors Influencing Outcome and Length of Stay in a Stroke Rehabilitation Unit .2. Comparison of 318 Screened and 248 Unscreened Patients. *Stroke, 8*(6), 657-662.

Ferber, S., & Karnath, H. O. (2001). Size perception in hemianopia and neglect. *Brain, 124*, 527-536.

Ferris, F. L., Kassoff, A., Bresnick, G. H., & Bailey, I. (1982). New Visual-Acuity Charts for Clinical Research. *American Journal of Ophthalmology, 94*(1), 91-96.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-Mental State - Practical Method for Grading Cognitive State of Patients for Clinician. *Journal of Psychiatric Research, 12*(3), 189-198.

Friedman, P. J. (1995). Stroke Outcome in Elderly People Living Alone. *Disability and Rehabilitation, 17*(2), 90-93.

Fujino, T., Kigazawa, K., & Yamada, R. (1986). Homonymous Hemianopia - a Retrospective Study of 140 Cases. *Neuro-Ophthalmology, 6*(1), 17-21.

Gall, C., Franke, G. H., & Sabel, B. A. (2010). Vision-related quality of life in first stroke patients with homonymous visual field defects. *Health and Quality of Life Outcomes, 8*, 33.

Gall, C., Lucklum, J., Sabel, B. A., & Franke, G. H. (2009). Vision- and Health-Related Quality of Life in Patients with Visual Field Loss after Postchiasmatic Lesions. *Investigative Ophthalmology & Visual Science, 50*(6), 2765-2776.

Gall, C., Mueller, I., Kaufmann, C., Franke, G. H., & Sabel, B. A. (2008). Visual field defects after cerebral lesions from the patient's perspective. Health- and vision-related quality of life assessed by SF-36 and NEI-VFQ. *Nervenarzt, 79*(2), 185-194.

Gall, C., Mueller, I., Gudlin, J., Lindig, A., Schlueter, D., Jobke, S., . . . Sabel, B. A. (2008). Vision- and health-related quality of life before and after vision restoration training in cerebrally damaged patients. *Restorative Neurology and Neuroscience, 26*(4-5), 341-353.

Gall, C., Wagenbreth, C., Sgorzaly, S., Franke, G. H., & Sabel, B. A. (2010). Parafoveal vision impairments and their influence on reading performance and self-evaluated reading abilities. *Graefes Archive for Clinical and Experimental Ophthalmology, 248*(6), 863-875.

Gassel, M. M., & Williams, D. (1963a). Visual Function in Patients with Homonymous Hemianopia .2. Oculomotor Mechanisms. *Brain, 86*(1), 1-36.

Gassel, M. M., & Williams, D. (1963b). Visual Function in Patients with Homonymous Hemianopia .3. Completion Phenomenon - Insight and Attitude to Defect - and Visual Functional Efficiency. *Brain, 86*(2), 229-260.

Gedik, S., Akman, A., & Akova, Y. A. (2007). Efficiency of Rarebit perimetry in the evaluation of homonymous hemianopia in stroke patients. *British Journal of Ophthalmology, 91*(8), 1065-1069.

Gilhotra, J. S., Mitchell, P., Healey, P. R., Cumming, R. G., & Currie, J. (2002). Homonymous visual field defects and stroke in an older population. *Stroke, 33*(10), 2417-2420.

Giorgi, R. G., Woods, R. L., & Peli, E. (2009). Clinical and Laboratory Evaluation of Peripheral Prism Glasses for Hemianopia. *Optometry and Vision Science, 86*(5), 492-502.

Gray, C. S., French, J. M., Bates, D., Cartlidge, N. E. F., Venables, G. S., & James, O. F. W. (1989). Recovery of Visual-Fields in Acute Stroke - Homonymous Hemianopia Associated with Adverse Prognosis. *Age and Ageing, 18*(6), 419-421.

Gray, L. G., Galetta, S. L., & Schatz, N. J. (1998). Vertical and horizontal meridian sparing in occipital lobe homonymous hemianopias. *Neurology, 50*(4), 1170-1173.

Gray, L. G., Galetta, S. L., Siegal, T., & Schatz, N. J. (1997). The central visual field in homonymous hemianopia - Evidence for unilateral foveal representation. *Archives of Neurology, 54*(3), 312-317.

Han, L., Law-Gibson, D., & Reding, M. (2002). Key neurological impairments influence function-related group outcomes after stroke. *Stroke, 33*(7), 1920-1924.

Han, S. W., Sohn, Y. H., Lee, P. H., Suh, B. C., & Choi, I. S. (2000). Pure homonymous hemianopia due to anterior choroidal artery territory infarction. *European Neurology, 43*(1), 35-38.

Hardiess, G., Papageorgiou, E., Schiefer, U., & Mallot, H. A. (2010). Functional compensation of visual field deficits in hemianopic patients under the influence of different task demands. *Vision Research, 50*(12), 1158-1172.

Harrington, D. (1961). Visual Field Character in Temporal and Occipital Lobe Lesions - Localizing Values of Congruity and Incongruity in Incomplete Homonymous Hemianopsia. *Archives of Ophthalmology, 66*(6), 778-792.

Hayes, A., Chen, C. S., Clarke, G., & Thompson, A. (2012). Functional improvements following the use of the NVT Vision Rehabilitation program for patients with hemianopia following stroke. *Neurorehabilitation, 31*(1), 19-30.

Heinsius, T., Bogousslavsky, J., & Van Melle, G. (1998). Large infarcts in the middle cerebral artery territory - Etiology and outcome patterns. *Neurology, 50*(2), 341-350.

Hellner, K. A., Jensen, W., & Mullerjensen, A. (1978). Videoprocessing Pupillographic Perimetry in Hemianopia. *Klinische Monatsblatter Fur Augenheilkunde, 172*(5), 731-735.

Hess, R. F., & Pointer, J. S. (1989). Spatial and Temporal Contrast Sensitivity in Hemianopia - a Comparative-Study of the Sighted and Blind Hemifields. *Brain, 112*, 871-894.

Hildebrandt, H., Giesselmann, H., & Sachsenheimer, W. (1999). Visual search and visual target detection in patients with infarctions of the left or right posterior or the right middle brain artery. *Journal of Clinical and Experimental Neuropsychology, 21*(1), 94-107.

Horton, J. C., & Hoyt, W. F. (1991). The Representation of the Visual-Field in Human Striate Cortex - a Revision of the Classic Holmes Map. *Archives of Ophthalmology, 109*(6), 816-824.

Huber, A. (1962). Homonymous Hemianopia After Occipital Lobectomy. *American Journal of Ophthalmology, 54*(4), 623-629.

Huxlin, K. R., Martin, T., Kelly, K., Riley, M., Friedman, D. I., Burgin, W. S., & Hayhoe, M. (2009). Perceptual Relearning of Complex Visual Motion after V1 Damage in Humans. *Journal of Neuroscience, 29*(13), 3981-3991.

Hyvarinen, L., Raninen, A. N., & Nasanen, R. E. (2002). Vision rehabilitation in homonymous hemianopia. *Neuro-Ophthalmology, 27*(1-3), 97-102.

Iorizzo, D. B., Riley, M. E., Hayhoe, M., & Huxlin, K. R. (2011). Differential impact of partial cortical blindness on gaze strategies when sitting and walking - An immersive virtual reality study. *Vision Research, 51*(10), 1173-1184.

Isa, K., Miyashita, K., Yanagimoto, S., Nagatsuka, K., & Naritomi, H. (2001). Homonymous defect of macular vision in ischemic stroke. *European Neurology, 46*(3), 126-130.

Ishiai, S., Furukawa, T., & Tsukagoshi, H. (1987). Eye-Fixation Patterns in Homonymous Hemianopia and Unilateral Spatial Neglect. *Neuropsychologia, 25*(4), 675-679.

Jacobson, D. M. (1997). The localizing value of a quadrantanopia. *Archives of Neurology, 54*(4), 401-404.

Jahnke, M. T., Denzler, P., Liebelt, B., Reichert, H., & Mauritz, K. H. (1995). Eye-Movements and Fixation Characteristics in Perception of Stationary Scenes - Normal Subjects as Compared to Patients with Visual Neglect Or Hemianopia. *European Journal of Neurology, 2*(4), 275-295.

Jamara, R. J., Van de velde, F., & Peli, E. (2003). Scanning eye movements in homonymous hemianopia documented by scanning laser ophthalmoscope retinal perimetry. *Optometry and Vision Science, 80*(7), 495-504.

Jobke, S., Kasten, E., & Sabel, B. A. (2009). Vision Restoration Through Extrastriate Stimulation in Patients With Visual Field Defects: A Double-Blind and Randomized Experimental Study. *Neurorehabilitation and Neural Repair, 23*(3), 246-255.

Johnson, J. H., & Cryan, M. (1979). Homonymous Hemianopia - Assessment and Nursing Management. *American Journal of Nursing, 79*(12), 2131-2135.

Julkunen, L., Tenovuo, O., Jaaskelainen, S., & Hamalainen, H. (2003). Rehabilitation of chronic post-stroke visual field defect with computer-assisted training - A clinical and neurophysiological study. *Restorative Neurology and Neuroscience, 21*(1-2), 19-28.

Kasneci, E., Sippel, K., Heister, M., Aehling, K., Rosenstiel, W., Schiefer, U., & Papageorgiou, E. (2014). Homonymous Visual Field Loss and Its Impact on Visual Exploration: A Supermarket Study. *Translational Vision Science & Technology, 3*(6), 2.

Kasten, E., Bunzenthal, U., & Sabel, B. A. (2006). Visual field recovery after vision restoration therapy (VRT) is independent of eye movements: An eye tracker study. *Behavioural Brain Research, 175*(1), 18-26.

Kasten, E., Muller-Oehring, E., & Sabel, B. A. (2001). Stability of visual field enlargements following computer-based restitution training - Results of a follow-up. *Journal of Clinical and Experimental Neuropsychology, 23*(3), 297-305.

Kasten, E., Poggel, D. A., & Sabel, B. A. (2000). Computer-based training of stimulus detection improves color and simple pattern recognition in the defective field of hemianopic subjects. *Journal of Cognitive Neuroscience, 12*(6), 1001-1012.

Kasten, E., & Sabel, B. A. (1995). Visual-Field Enlargement After Computer-Training in Brain-Damaged Patients with Homonymous Deficits - an Open Pilot Trial. *Restorative Neurology and Neuroscience, 8*(3), 113-127.

Kasten, E., Wuest, S., & Sabel, B. A. (1998). Residual vision in transition zones in patients with cerebral blindness. *Journal of Clinical and Experimental Neuropsychology, 20*(5), 581-598.

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

Kattah, J. C., Dennis, P., Kolsky, M. P., Schellinger, D., & Cohan, S. L. (1981). Computed-Tomography in Patients with Homonymous Visual-Field Defects .A. Clinico-Radiologic Correlation. *Computerized Tomography, 5*(4), 301-312.

Kaul, S. N., Boulay, G. H. D., Kendall, B. E., & Russell, R. W. R. (1974). Relationship between Visual-Field Defect and Arterial-Occlusion in Posterior Cerebral-Circulation. *Journal of Neurology Neurosurgery and Psychiatry, 37*(9), 1022-1030.

Kearns, T. P., & Rucker, C. W. (1959). Clinics in Perimetry No-3 - Incongruous Homonymous Hemianopsia. *American Journal of Ophthalmology, 47*(3), 317-321.

Kedar, S., Zhang, X., Lynn, M. J., Newman, N. J., & Biousse, V. (2006). Pediatric homonymous hemianopia. *Journal of Aapos, 10*(3), 249-252.

Kedar, S., Zhang, X., Lynn, M. J., Newman, N. J., & Biousse, V. (2007). Congruency in homonymous hemianopia. *American Journal of Ophthalmology, 143*(5), 772-780.

Keller, H. M., Meyer, W. E., Valavanis, A., & Imhof, H. G. (1988). Hemianopia of Vascular Origin. *Klinische Monatsblatter Fur Augenheilkunde, 192*(5), 532-542.

Keller, I., & Lefin-Rank, G. (2010). Improvement of Visual Search After Audiovisual Exploration Training in Hemianopic Patients. *Neurorehabilitation and Neural Repair, 24*(7), 666-673.

Kerkhoff, G. (1999). Restorative and compensatory therapy approaches in cerebral blindness - a review. *Restorative Neurology and Neuroscience, 15*(2-3), 255-271.

Kerkhoff, G., Artinger, F., & Ziegler, W. (1999). Contrasting spatial hearing deficits in hemianopia and spatial neglect. *Neuroreport, 10*(17), 3555-3560.

Kerkhoff, G., Munssinger, U., Eberlestrauss, G., & Stogerer, E. (1992). Rehabilitation of Hemianopic Alexia in Patients with Postgeniculate Visual Field Defects. *Neuropsychological Rehabilitation, 2*(1), 21-42.

Kerkhoff, G., Munssinger, U., Haaf, E., Eberlestrauss, G., & Stogerer, E. (1992). Rehabilitation of Homonymous Scotomas in Patients with Postgeniculate Damage of the Visual-System - Saccadic Compensation Training. *Restorative Neurology and Neuroscience, 4*(4), 245-254.

Kerkhoff, G., Munssinger, U., & Meier, E. K. (1994). Neurovisual Rehabilitation in Cerebral Blindness. *Archives of Neurology, 51*(5), 474-481.

Kerkhoff, G., Schaub, J., & Zihl, J. (1990). Assessment of Cerebral Visual Disorders by Patient-Questionnaire. *Nervenarzt, 61*(12), 711-718.

Kiyosawa, M., Bosley, T. M., Kushner, M., Jamieson, D., Alavi, A., & Reivich, M. (1990). Middle Cerebral-Artery Strokes Causing Homonymous Hemianopia - Positron Emission Tomography. *Annals of Neurology, 28*(2), 180-183.

Knox, D. L., & Cogan, D. G. (1962). Eye Pain and Homonymous Hemianopia. *American Journal of Ophthalmology, 54*(6), 1091-1093.

Koehler, P. J., Endtz, L. J., Velde, J. T., & Hekster, R. E. M. (1986). Aware Or Non-Aware - on the Significance of Awareness for Localization of the Lesion Responsible for Homonymous Hemianopia. *Journal of the Neurological Sciences, 75*(3), 255-262.

Kollias, S. S., Landau, K., Khan, N., Golay, X., Bernays, R., Yonekawa, Y., & Valavanis, A. (1998). Functional evaluation using magnetic resonance imaging of the visual cortex in patients with retrochiasmatic lesions. *Journal of Neurosurgery, 89*(5), 780-790.

Kolmel, H. W. (1984). Colored Patterns in Hemianopic Fields. *Brain, 107*(MAR), 155-167.

Kolmel, H. W. (1985). Complex Visual Hallucinations in the Hemianopic Field. *Journal of Neurology Neurosurgery and Psychiatry, 48*(1), 29-38.

Kooijman, A. C., Melis-Dankers, B. J. M., Peli, E., Brouwer, W. H., Pijnakker, P., Van Delden, G., . . . Postema, F. (2008). The Introduction of Bioptic Driving in the Netherlands. *Visual Impairment Research, 10*, 1-6.

Kooijman, A. C., Stellingwerf, N., Van Schoot, E. A. J., Cornelissen, F. W., & Van der Wildt, G. J. (1994). Groningen Edge Contrast Chart (Gecko) and Glare Measurements. *Investigative Ophthalmology & Visual Science, 35*(4), 1371-1371.

Landis, T., & Regard, M. (1988). Hemianopia and Agnosia. *Klinische Monatsblatter Fur Augenheilkunde, 192*(5), 525-528.

Lane, A. R., Smith, D. T., Ellison, A., & Schenk, T. (2010). Visual exploration training is no better than attention training for treating hemianopia. *Brain, 133*, 1717-1728.

Langelaan, M., Wouters, B., Moll, A., Boer, M., & Rens, G. (2005). Intra- and interrater agreement and reliability of the Functional Field Score. *Ophthalmic and Physiological Optics, 25*(2), 136-142.

Leff, A. P., Crewes, H., Plant, G. T., Scott, S. K., Kennard, C., & Wise, R. J. S. (2001). The functional anatomy of single-word reading in patients with hemianopic and pure alexia. *Brain, 124*, 510-521.

Leff, A. P., Scott, S. K., Crewes, H., Hodgson, T. L., Cowey, A., Howard, D., & Wise, R. J. S. (2000). Impaired reading in patients with right hemianopia. *Annals of Neurology, 47*(2), 171-178.

Leh, S. E., Mullen, K. T., & Ptito, A. (2006). Absence of S-cone input in human blindsight following hemispherectomy. *European Journal of Neuroscience, 24*(10), 2954-2960.

Leo, F., Bolognini, N., Passamonti, C., Stein, B. E., & Ladavas, E. (2008). Cross-modal localization in hemianopia: new insights on multisensory integration. *Brain, 131*, 855-865.

Lepore, F. E. (2001). The preserved temporal crescent: The clinical implications of an "endangered" finding. *Neurology, 57*(10), 1918-1921.

Lesevre, N. (1982). Chronotopographical Analysis of the Human Evoked-Potential in Relation to the Visual-Field (Data from Normal Individuals and Hemianopic Patients). *Annals of the New York Academy of Sciences, 388*(JUN), 156-182.

Lewald, J., Peters, S., Tegenthoff, M., & Hausmann, M. (2009a). Dissociation of auditory and visual straight ahead in hemianopia. *Brain Research, 1287*, 111-117.

Lewald, J., Peters, S., Tegenthoff, M., & Hausmann, M. (2009b). Distortion of auditory space in hemianopia. *European Journal of Neuroscience, 30*(7), 1401-1411.

Lindeboom, J., & Jonker, C. (1989). *Amsterdamse Dementie-Screeningstest ADS-6. Handleiding.* Pearson Assessment and Information B.V.

Maaijwee, K. J., Meulendijks, C. F. M., Radner, W., Van Meurs, J. C., & Hoyng, C. B. (2007). The Dutch version of the Radner Reading Chart for assessing vision function. *Nederlands Tijdschrift Voor Geneeskunde, 151*(45), 2494-2497.

Maccolini, E., Andreoli, A., Valde, G., Ghini, M., & Fulco, L. (1986). Hemifield Pattern-Reversal Visual Evoked-Potentials (Veps) in Retrochiasmal Lesions with Homonymous Visual-Field Defect. *Italian Journal of Neurological Sciences, 7*(4), 437-442.

Machner, B., Sprenger, A., Sander, T., Heide, W., Kimmig, H., Helmchen, C., & Koempf, D. (2009). Visual Search Disorders in Acute and Chronic Homonymous Hemianopia Lesion Effects and Adaptive Strategies. *Basic and Clinical Aspects of Vertigo and Dizziness, 1164*, 419-426.

Mangione, C., Lee, P., Gutierrez, P., Spritzer, K., Berry, S., & Hays, R. (2001). Development of the 25-item National Eye Institute Visual Function Questionnaire. *Archives of Ophthalmology, 119*(7), 1050-1058.

Mannan, S. K., Pambakian, A. L. M., & Kennard, C. (2010). Compensatory strategies following visual search training in patients with homonymous hemianopia: an eye movement study. *Journal of Neurology, 257*(11), 1812-1821.

Manor, R. S. (1989). Entopic Phenomena in Pregeniculate and Postgeniculate Hemianopia with Splitting of Macula by Perimetry. *American Journal of Ophthalmology, 108*(5), 585-591.

Marshall, R. S., Chmayssani, M., O'Brien, K. A., Handy, C., & Greenstein, V. C. (2010). Visual field expansion after visual restoration therapy. *Clinical Rehabilitation, 24*(11), 1027-1035.

Marshall, R. S., Ferrera, J. J., Barnes, A., Zhang, X., O'Brien, K. A., Chmayssani, M., . . . Lazar, R. M. (2008). Brain activity associated with stimulation therapy of the visual borderzone in hemianopic stroke patients. *Neurorehabilitation and Neural Repair, 22*(2), 136-144.

Martin, T., Riley, M. E., Kelly, K. N., Hayhoe, M., & Huxlin, K. R. (2007). Visually-guided behavior of homonymous hemianopes in a naturalistic task. *Vision Research, 47*(28), 3434-3446.

Matthews, E. E., Cook, P. F., Terada, M., & Aloia, M. S. (2010). Randomizing Research Participants: Promoting Balance and Concealment in Small Samples. *Research in Nursing & Health, 33*(3), 243-253.

Mattingley, J. B., Berberovic, N., Corben, L., Slavin, M. J., Nicholls, M. E. R., & Bradshaw, J. L. (2004). The greyscales task: a perceptual measure following unilateral hemispheric of attentional bias damage. *Neuropsychologia, 42*(3), 387-394.

Matwijecky, C., & Steinbok, P. (1982). Hemianopia - a Presenting Feature of Acute Epidural Hematomas. *Neurosurgery, 11*(2), 247-249.

Mcauley, D. L., & Russell, R. W. R. (1979). Correlation of Cat Scan and Visual-Field Defects in Vascular-Lesions of the Posterior Visual Pathways. *Journal of Neurology Neurosurgery and Psychiatry, 42*(4), 298-311.

McDonald, S. A., Spitsyna, G., Shillcock, R. C., Wise, R. J. S., & Leff, A. P. (2006). Patients with hemianopic alexia adopt an inefficient eye movement strategy when reading text. *Brain, 129*, 158-167.

Meienberg, O. (1981). Sparing of the Temporal Crescent in Homonymous Hemianopia and its Significance for Visual Orientation. *Neuro-Ophthalmology, 2*(2), 129-134.

Meienberg, O. (1983). Clinical Examination of Saccadic Eye-Movements in Hemianopia. *Neurology, 33*(10), 1311-1315.

Meienberg, O. (1988). Eye-Movement Patterns in Homonymous Hemianopia and Visual Hemineglect. *Klinische Monatsblatter Fur Augenheilkunde, 192*(2), 108-112.

Meienberg, O., Harrer, M., & Wehren, C. (1986). Oculographic Diagnosis of Hemineglect in Patients with Homonymous Hemianopia. *Journal of Neurology, 233*(2), 97-101.

Meienberg, O., Zangemeister, W. H., Rosenberg, M., Hoyt, W. F., & Stark, L. (1981). Saccadic Eye-Movement Strategies in Patients with Homonymous Hemianopia. *Annals of Neurology, 9*(6), 537-544.

Meyers, J. E., & Meyers, K. R. (1995). *Rey Complex Figure Test and Recognition Trial (RCFT). Professional manual.* Lutz: Psychological Assessment Resources, Inc.

Miki, A., Liu, G. T., Modestino, E. J., Bonhomme, G. R., Liu, C. S. J., & Haselgrove, J. C. (2005). Decreased lateral geniculate nucleus activation in retrogeniculate hemianopia demonstrated by functional magnetic resonance imaging at 4Tesla. *Ophthalmologica, 219*(1), 11-15.

Miki, A., Nakajima, T., Fujita, M., Takagi, M., & Abe, H. (1996). Functional magnetic resonance imaging in homonymous hemianopsia. *American Journal of Ophthalmology, 121*(3), 258-266.

Miyai, I., Blau, A. D., Reding, M. J., & Volpe, B. T. (1997). Patients with stroke confined to basal ganglia have diminished response to rehabilitation efforts. *Neurology, 48*(1), 95-101.

Moedden, C., Behrens, M., Damke, I., Eilers, N., Kastrup, A., & Hildebrandt, H. (2012). A Randomized Controlled Trial Comparing 2 Interventions for Visual Field Loss With Standard Occupational Therapy During Inpatient Stroke Rehabilitation. *Neurorehabilitation and Neural Repair, 26*(5), 463-469.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods, 11*(2), 364-386.

Mueller, I., Gall, C., Kasten, E., & Sabel, B. A. (2008). Long-term learning of visual functions in patients after brain damage. *Behavioural Brain Research, 191*(1), 32-42.

Muller-Oehring, E. M., Kasten, E., Poggel, D. A., Schulte, T., Strasburger, H., & Sabel, B. A. (2003). Neglect and hemianopia superimposed. *Journal of Clinical and Experimental Neuropsychology, 25*(8), 1154-1168.

Nelles, G., De Greiff, A., Pscherer, A., Forsting, M., Gerhard, H., Esser, J., & Diener, H. C. (2007). Cortical activation in hemianopia after stroke. *Neuroscience Letters, 426*(1), 34-38.

Nelles, G., De Greiff, A., Pscherer, A., Stude, P., Forsting, M., Hufnagel, A., . . . Diener, H. C. (2007). Saccade induced cortical activation in patients with post-stroke visual field defects. *Journal of Neurology, 254*(9), 1244-1252.

Nelles, G., Esser, J., Eckstein, A., Tiede, A., Gerhard, H., & Diener, H. C. (2001). Compensatory visual field training for patients with hemianopia after stroke. *Neuroscience Letters, 306*(3), 189-192.

Nelles, G., Pscherer, A., De Greiff, A., Forsting, M., Gerhard, H., Esser, J., & Diener, H. C. (2009). Eye-movement training-induced plasticity in patients with post-stroke hemianopia. *Journal of Neurology, 256*(5), 726-733.

Nelles, G., Pscherer, A., De Greiff, A., Gerhard, H., Forsting, M., Esser, J., & Diener, H. C. (2010). Eye-movement training-induced changes of visual field representation in patients with post-stroke hemianopia. *Journal of Neurology, 257*(11), 1832-1840.

Newman, S. A., & Miller, N. R. (1983). Optic Tract Syndrome - Neuro-Ophthalmologic Considerations. *Archives of Ophthalmology, 101*(8), 1241-1250.

Ng, Y., Stein, J., Salles, S., & Black-Schaffer, R. (2005). Clinical characteristics and rehabilitation outcomes of patients with posterior cerebral artery stroke. *Archives of Physical Medicine and Rehabilitation, 86*(11), 2138-2143.

Norbeck, J. S. (1984). Modification of recent life event questionnaires for use with female respondents. *Research in Nursing and Health, 7*, 61-71.

Ostertag, C. B., & Unsold, R. (1981). Correlation of Infarctions of the Visual-Cortex with Homonymous Visual-Field Defects - a Computer Tomographic Study. *Archiv Fur Psychiatrie Und Nervenkrankheiten, 230*(3), 265-274.

Owsley, C., & McGwin, G., Jr. (2010). Vision and driving. *Vision Research, 50*(23), 2348-2361.

Pai, M. C. (1997). Topographic disorientation: Two cases. *Journal of the Formosan Medical Association, 96*(8), 660-663.

Pambakian, A. L. M., & Kennard, C. (1997). Can visual function be restored in patients with homonymous hemianopia? *British Journal of Ophthalmology, 81*(4), 324-328.

Pambakian, A. L. M., Mannan, S. K., Hodgson, T. L., & Kennard, C. (2004). Saccadic visual search training: a treatment for patients with homonymous hemianopia. *Journal of Neurology Neurosurgery and Psychiatry, 75*(10), 1443-1448.

Pambakian, A. L. M., Wooding, D. S., Patel, N., Morland, A. B., Kennard, C., & Mannan, S. K. (2000). Scanning the visual world: a study of patients with homonymous hemianopia. *Journal of Neurology Neurosurgery and Psychiatry, 69*(6), 751-759.

Papageorgiou, E., Hardiess, G., Schaeffel, F., Wiethoelter, H., Karnath, H., Mallot, H., . . . Schiefer, U. (2007). Assessment of vision-related quality of life in patients with homonymous visual field defects. *Graefes Archive for Clinical and Experimental Ophthalmology, 245*(12), 1749-1758.

Papageorgiou, E., Ticini, L. F., Hardiess, G., Schaeffel, F., Wiethoelter, H., Mallot, H. A., . . . Karnath, H. -. (2008). The pupillary light reflex pathway - Cytoarchitectonic probabilistic maps in hemianopic patients. *Neurology, 70*(12), 956-963.

Paparella, G., Piccoli, S., Brouwer, W. H., & Hunter, J. (2009). *Cognitive impairment and dementia. In Hunter J, Vries J de, Brown Y, Hekstra A, editors. Handbook of Disabled Driver Assessment.* (pp. 381-390). Ljubljana: Institute for Rehabilitation.

Paramei, G. V., & Sabel, B. A. (2008). Contour-integration deficits on the intact side of the visual field in hemianopia patients. *Behavioural Brain Research, 188*(1), 109-124.

Parker, W. T., McGwin, G., Jr., Wood, J. M., Elgin, J., Vaphiades, M. S., Kline, L. B., & Owsley, C. (2011). Self-Reported Driving Difficulty by Persons with Hemianopia and Quadrantanopia. *Current Eye Research, 36*(3), 270-277.

Passamonti, C., Bertini, C., & Ladavas, E. (2009). Audio-visual stimulation improves oculomotor patterns in patients with hemianopia. *Neuropsychologia, 47*(2), 546-555.

Patel, A. T., Duncan, P. W., Lai, S. M., & Studenski, S. (2000). The relation between impairments and functional outcomes poststroke. *Archives of Physical Medicine and Rehabilitation, 81*(10), 1357-1363.

Peli, E. (2000). Field expansion for homonymous hemianopia by optically induced peripheral exotropia. *Optometry and Vision Science, 77*(9), 453-464.

Perenin, M. T. (1991). Discrimination of Motion Direction in Perimetrically Blind Fields. *Neuroreport, 2*(7), 397-400.

Pessin, M. S., Lathi, E. S., Cohen, M. B., Kwan, E. S., Hedges, T. R., & Caplan, L. R. (1987). Clinical-Features and Mechanism of Occipital Infarction. *Annals of Neurology, 21*(3), 290-299.

Pflugshaupt, T., Von Wartburg, R., Wurtz, P., Chaves, S., Deruaz, A., Nyffeler, T., . . . Mueri, R. M. (2009). Linking physiology with behaviour: Functional specialisation of the visual field is reflected in gaze patterns during visual search. *Vision Research, 49*(2), 237-248.

Piersma, D., Fuermaier, A. B. M., de Waard, D., Davidse, R. J., de Groot, J., Doumen, M. J. A., . . . Tucha, O. (2016). Prediction of Fitness to Drive in Patients with Alzheimer's Dementia. *PLoS ONE, 11*(2), e0149566.

Pizzamiglio, L., Antonucci, G., Judica, A., Montenero, P., Razzano, C., & Zoccolotti, P. (1992). Cognitive Rehabilitation of the Hemineglect Disorder in Chronic-Patients with Unilateral Right Brain-Damage. *Journal of Clinical and Experimental Neuropsychology, 14*(6), 901-923.

Pocock, S. J., & Simon, R. (1975). Sequential Treatment Assignment with Balancing for Prognostic Factors in Controlled Clinical Trial. *Biometrics, 31*(1), 103-115.

Poggel, D. A., Kasten, E., Mueller-Oehring, E. M., Bunzenthal, U., & Sabel, B. A. (2006). Improving residual vision by attentional cueing in patients with brain lesions. *Brain Research, 1097*, 142-148.

Poggel, D. A., Kasten, E., & Sabel, B. A. (2004). Attentional cueing improves vision restoration therapy in patients with visual field defects. *Neurology, 63*(11), 2069-2076.

Poggel, D. A., Mueller, I., Kasten, E., Bunzenthal, U., & Sabel, B. A. (2010). Subjective and objective outcome measures of computer-based vision restoration training. *Neurorehabilitation, 27*(2), 173-187.

Poggel, D. A., Mueller, I., Kasten, E., & Sabel, B. A. (2008). Multifactorial predictors and outcome variables of vision restoration training in patients with post-geniculate visual field loss. *Restorative Neurology and Neuroscience, 26*(4-5), 321-339.

Poggel, D. A., Mueller-Oehring, E. M., Gothe, J., Kenkel, S., Kasten, E., & Sabel, B. A. (2007). Visual hallucinations during spontaneous and training-induced visual field recovery. *Neuropsychologia, 45*(11), 2598-2607.

Poggel, D. A., Mueller-Oehring, E. M., Kasten, E., Bunzenthal, U., & Sabel, B. A. (2008). The topography of training-induced visual field recovery: Perimetric maps and subjective representations. *Visual Cognition, 16*(8), 1059-1077.

Pollock, A., Hazelton, C., Henderson, C. A., Angilley, J., Dhillon, B., Langhorne, P., . . . Shahani, U. (2011). Interventions for visual field defects in patients with stroke. *Cochrane Database of Systematic Reviews,* (10), CD008388.

Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L. C., LaMantia, A., McNamara, J. O., . . . Williams, S. M. (2001). *Neuroscience* (2nd ed.). Sunderland (MA): Sinauer Associates.

Racette, L., & Casson, E. J. (2005). The impact of visual field loss on driving performance: Evidence from on-road driving assessments. *Optometry and Vision Science, 82*(8), 668-674.

Radner, T., Willinger, U., Obermayer, W., Mudrich, C., Velikay-Parel, M., & Eisenwort, B. (1998). A new German reading chart for the simultaneous evaluation of reading acuity and reading speed. *Klinische Monatsblatter Fur Augenheilkunde, 213*(3), 174-181.

Rafal, R., Smith, J., Krantz, J., Cohen, A., & Brennan, C. (1990). Extrageniculate Vision in Hemianopic Humans - Saccade Inhibition by Signals in the Blind Field. *Science, 250*(4977), 118-121.

Raninen, A., Vanni, S., Hyvarinen, L., & Nasanen, R. (2007). Temporal sensitivity in a hemianopic visual field can be improved by long-term training using flicker stimulation. *Journal of Neurology Neurosurgery and Psychiatry, 78*(1), 66-73.

Reding, M. J., & Potes, E. (1988). Rehabilitation Outcome Following Initial Unilateral Hemispheric Stroke - Life Table Analysis Approach. *Stroke, 19*(11), 1354-1358.

Regeling Eisen Geschiktheid 2000. Retrieved from http://wetten.overheid.nl/BWBR0011362/ geldigheidsdatum_08-04-2013

Reinhard, J., Schreiber, A., Schiefer, U., Kasten, E., Sabel, B. A., Kenkel, S., . . . Trauzettel-Klosinski, S. (2005). Does visual restitution training change absolute homonymous visual field defects? A fundus controlled study. *British Journal of Ophthalmology, 89*(1), 30-35.

Reitan, R. M. (1958). Validity of the trail making test as an indicator of organic brain damage. *Perceptual and Motor Skills, 8*, 271-276.

Rockwell, T. H. (1972). *Skills, judgement and information acquisitionin driving. In T.W. Forbes (Ed.)* (pp. 133-164). New York: Wiley-Interscience.

Romano, J. G., Schulz, P., Kenkel, S., & Todd, D. P. (2008). Visual field changes after a rehabilitation intervention: Vision restoration therapy. *Journal of the Neurological Sciences, 273*(1-2), 70-74.

Rondot, P., Odier, F., & Valade, D. (1992). Postural Disturbances due to Homonymous Hemianopic Visual Ataxia. *Brain, 115*, 179-188.

Rossi, P. W., Kheyfets, S., & Reding, M. J. (1990). Fresnel Prisms Improve Visual-Perception in Stroke Patients with Homonymous Hemianopia Or Unilateral Visual Neglect. *Neurology, 40*(10), 1597-1599.

Roth, T., Sokolov, A. N., Messias, A., Roth, P., Weller, M., & Trauzettel-Klosinski, S. (2009). Comparing explorative saccade and flicker training in hemianopia A randomized controlled study. *Neurology, 72*(4), 324-331.

Rothschild, F. S., & Streifler, M. (1952). On Eyedness in Homonymous Hemianopia. *Journal of Nervous and Mental Disease, 116*(1), 59-64.

Saan, R. J., & Deelman, B. G. (1986). *De 15-Woorden Tests A en B (een voorlopige handleiding)* Groningen: Afdeling Neuropsychologie, AZG (interne publicatie).

Sabel, B. A., Kenkel, S., & Kasten, E. (2004). Vision restoration therapy (VRT) efficacy as assessed by comparative perimetric analysis and subjective questionnaires. *Restorative Neurology and Neuroscience, 22*(6), 399-420.

Sahraie, A., MacLeod, M., Trevethan, C. T., Robson, S. E., Olson, J. A., Callaghan, P., & Yip, B. (2010). Improved detection following Neuro-Eye Therapy in patients with post-geniculate brain damage. *Experimental Brain Research, 206*(1), 25-34.

Sahraie, A., Trevethan, C. T., MacLeod, M. J., Murray, A. D., Olson, J. A., & Weiskrantz, L. (2006). Increased sensitivity after repeated stimulation of residual spatial channels in blindsight. *Proceedings of the National Academy of Sciences of the United States of America, 103*(40), 14971-14976.

Sahraie, A., Trevethan, C. T., & MacLeod, M. (2008). Temporal properties of spatial channel of processing in hemianopia. *Neuropsychologia, 46*(3), 879-885.

Saj, A., Honore, J., Richard, C., Bernati, T., & Rousseaux, M. (2010). Hemianopia and Neglect Influence on Straight-Ahead Perception. *European Neurology, 64*(5), 297-303.

Savino, P. J., Paris, M., Schatz, N. J., Orr, L. S., & Corbett, J. J. (1978). Optic Tract Syndrome - Review of 21 Patients. *Archives of Ophthalmology, 96*(4), 656-663.

Savir, H., Michelson, I., David, C., Mendelson, L., & Najenson, T. (1977). Homonymous Hemianopia and Rehabilitation in 15 Cases of Cci. *Scandinavian Journal of Rehabilitation Medicine, 9*(4), 151-153.

Schadow, J., Dettler, N., Paramei, G. V., Lenz, D., Fruend, I., Sabel, B. A., & Herrmann, C. S. (2009). Impairments of Gestalt perception in the intact hemifield of hemianopic patients are reflected in gamma-band EEG activity. *Neuropsychologia, 47*(2), 556-568.

Schafer, J. L., & Graham, J. W. (2002). Missing data: our view of the state of the art. *Psychological Methods, 7*(2), 147-177.

Scharli, H., Harman, A. M., & Hogben, J. H. (1999). Blindsight in subjects with homonymous visual field defects. *Journal of Cognitive Neuroscience, 11*(1), 52-66.

Schenkenberg, T., Bradford, D. C., & Ajax, E. T. (1980). Line Bisection and Unilateral Visual Neglect in Patients with Neurologic Impairment. *Neurology, 30*(5), 509-517.

Schmand, B., Lindeboom, J., & Van Harskamp, F. (1992). *De Nederlandse leestest voor volwassenen*. Lisse: Swets & Zeitlinger.

Schmielau, F., & Wong, E. K., Jr. (2007). Recovery of visual fields in brain-lesioned patients by reaction perimetry treatment. *Journal of Neuroengineering and Rehabilitation, 4*, 31.

Schoepf, D., & Zangemeister, W. H. (1993). Correlation of Ocular Motor Reading Strategies to the Status of Adaptation in Patients with Hemianopic Visual-Field Defects. *Annals of the New York Academy of Sciences, 682*, 404-408.

Schreiber, A., Vonthein, R., Reinhard, J., Trauzettel-Klosinski, S., Connert, C., & Schiefer, U. (2006). Effect of visual restitution training on absolute homonymous scotomas. *Neurology, 67*(1), 143-145.

Schuett, S., Heywood, C. A., Kentridge, R. W., Dauner, R., & Zihl, J. (2012). Rehabilitation of reading and visual exploration in visual field disorders: transfer or specificity? *Brain, 135*, 912-921.

Schuett, S., Heywood, C. A., Kentridge, R. W., & Zihl, J. (2008). Rehabilitation of hemianopic dyslexia: are words necessary for re-learning oculomotor control. *Brain, 131*, 3156-3168.

Schulte, T., Strasburger, H., Muller-Oehring, E. M., Kasten, E., & Sabel, B. A. (1999). Automobile driving performance of brain-injured patients with visual field defects. *American Journal of Physical Medicine & Rehabilitation, 78*(2), 136-142.

Serafeti, E. A. (1969). Psychological Effects of Sudden Complete Hemianopia. *Perceptual and Motor Skills, 28*(1), 206.

Smith, D. T., Lane, A. R., & Schenk, T. (2008). Arm position does not attenuate visual loss in patients with homonymous field deficits. *Neuropsychologia, 46*(9), 2320-2325.

Smith, J. L. (1962). Homonymous Hemianopia - a Review of 100 Cases. *American Journal of Ophthalmology, 54*(4), 616-623.

Spinhoven, P., Ormel, J., Sloekers, P. P. A., Kempen, G. I. J. M., Speckens, A. E. M., & VanHemert, A. M. (1997). A validation study of the Hospital Anxiety and Depression Scale (HADS) in different groups of Dutch subjects. *Psychological Medicine, 27*(2), 363-370.

Spitzyna, G. A., Wise, R. J. S., McDonald, S. A., Plant, G. T., Kidd, D., Crewes, H., & Leff, A. P. (2007). Optokinetic therapy improves text reading in patients with hemianopic alexia - A controlled trial. *Neurology, 68*(22), 1922-1930.

Stoerig, P., Zontanou, A., & Cowey, A. (2002). Aware or unaware: Assessment of cortical blindness in four men and a monkey. *Cerebral Cortex, 12*(6), 565-574.

Suzuki, Y., Horie, C., Kiyosawa, M., Nariai, T., Mochizuki, M., Oda, K., . . . Ishii, K. (2008). Measurement of the C-11-flumazenil binding in the visual cortex predicts the prognosis of hemianopia. *Journal of the Neurological Sciences, 268*(1-2), 102-107.

Szlyk, J. P., Brigell, M., & Seiple, W. (1993). Effects of Age and Hemianopic Visual-Field Loss on Driving. *Optometry and Vision Science, 70*(12), 1031-1037.

Szlyk, J. P., Seiple, W., Stelmack, J., & McMahon, T. (2005). Use of prisms for navigation and driving in hemianopic patients. *Ophthalmic and Physiological Optics, 25*(2), 128-135.

Tant, M. L. M. (2002). *Visual performance in homonymous hemianopia: assessment, training and driving*. Groningen: University of Groningen.

Tant, M. L. M., Brouwer, W. H., Cornelissen, F. W., & Kooijman, A. C. (2002). Driving and visuospatial performance in people with hemianopia. *Neuropsychological Rehabilitation, 12*(5), 419-437.

Tant, M. L. M., Cornelissen, F. W., Kooijman, A. C., & Brouwer, W. H. (2002). Hemianopic visual field defects elicit hemianopic scanning. *Vision Research, 42*(10), 1339-1348.

Tant, M. L. M., Kuks, J. B. M., Kooijman, A. C., Cornelissen, F. W., & Brouwer, W. H. (2002). Grey scales uncover similar attentional effects in homonymous hemianopia and visual hemi-neglect. *Neuropsychologia, 40*(8), 1474-1481.

Tiel, K., & Kolmel, H. W. (1991). Patterns of Recovery from Homonymous Hemianopia Subsequent to Infarction in the Distribution of the Posterior Cerebral-Artery. *Neuro-Ophthalmology, 11*(1), 33-39.

Toepfer, A., Kasten, E., Guenther, T., & Sabel, B. A. (2008). Perimetry While Moving the Eyes: Implications for the Variability of Visual Field Defects. *Journal of Neuro-Ophthalmology, 28*(4), 308-319.

Traccis, S., Puliga, M. V., Ruiu, M. C., Marras, M. A., & Rosati, G. (1991). Unilateral Occipital Lesion Causing Hemianopia Affects the Acoustic Saccadic Programming. *Neurology, 41*(10), 1633-1638.

Trauzettel-Klosinski, S. (1997). Eccentric fixation with hemianopic field defects - A valuable strategy to improve reading ability and an indication of cortical plasticity. *Neuro-Ophthalmology, 18*(3), 117-131.

Trauzettel-Klosinski, S., & Brendler, K. (1998). Eye movements in reading with hemianopic field defects: the significance of clinical parameters. *Graefes Archive for Clinical and Experimental Ophthalmology, 236*(2), 91-102.

Trauzettel-Klosinski, S., & Reinhard, J. (1998). The vertical field border in hemianopia and its significance for fixation and reading. *Investigative Ophthalmology & Visual Science, 39*(11), 2177-2186.

Trobe, J. D., Lorber, M. L., & Schlezinger, N. S. (1973). Isolated Homonymous Hemianopia - Review of 104-Cases. *Archives of Ophthalmology, 89*(5), 377-381.

Turano, K., Geruschat, D., Stahl, J., & Massof, R. (1999). Perceived visual ability for independent mobility in persons with retinitis pigmentosa. *Investigative Ophthalmology & Visual Science, 40*(5), 865-877.

Vallar, G., Sandroni, P., Rusconi, M. L., & Barbieri, S. (1991). Hemianopia, Hemianesthesia, and Spatial Neglect - a Study with Evoked-Potentials. *Neurology, 41*(12), 1918-1922.

Van der Elst, W., Van Boxtel, M., Van Breukelen, G., & Jolles, J. (2005). Rey's verbal learning test: Normative data for 1855 healthy participants aged 24-81 years and the influence of age, sex, education, and mode of presentation. *Journal of the International Neuropsychological Society, 11*(3), 290-302.

Van der Sterre, G. W., Van de Graaf, E. S., Verezen, C. A., Meulendijks, C. F., Schouten, J. S., Saxena, R., . . . Simonsz, H. J. (2001). National Eye Institute Visual Functioning Questionnaire-25: Nederlandse Consensus Vertaling (VFQ-25/NL). Versie 2001. Retrieved from http://www.erasmusmc.nl/mage/publicaties/aanvullingen/3503982/interviewer+versie++VFQ25-N1.pdf

Van der Stigchel, S., Nijboer, T. C. W., Bergsma, D. P., Abegg, M., & Barton, J. J. S. (2010). Anomalous global effects induced by 'blind' distractors in visual hemifield defects. *Brain and Cognition, 74*(1), 66-73.

Van der Wildt, G. J., & Bergsma, D. P. (1997). Visual field enlargement by neuropsychological training of a hemianopsia patient. *Documenta Ophthalmologica, 93*(4), 277-292.

Van Stavern, G., Biousse, V., Lynn, M., Simon, D., & Newman, N. (2001). Neuro-ophthalmic manifestations of head trauma. *Journal of Neuro-Ophthalmology, 21*(2), 112-117.

Vaphiades, M. S., Celesia, G. G., & Brigell, M. G. (1996). Positive spontaneous visual phenomena limited to the hemianopic field in lesions of central visual pathways. *Neurology, 47*(2), 408-417.

Vlakveld, W. (2011). Hazard anticipation, age and experience. *Hazard anticipation of young novice drivers: Assessing and enhancing the capabilities of young novice drivers to anticipate latent hazards in road and traffic situations* (pp. 115-170). Leidschendam: SWOV.

Vliegen, J., & Koch, H. R. (1974). Clinical Meaning of Homonymous Hemianopia. *Nervenarzt, 45*(9), 449-457.

Vola, J. (1990). Color-Vision Deficiencies in Lateral Homonymous Hemianopia. *Neuro-Ophthalmology, 10*(3), 139-143.

Wagenbreth, C., Franke, G. H., Sabel, B. A., & Gall, C. (2010). Impairments of Vision- and Health-Related Quality of Life in Stroke Patients with Homonymous Visual Field Defects Depend on Severity of Visual Function Loss. *Klinische Monatsblatter Fur Augenheilkunde, 227*(2), 138-148.

Walker, R., Mannan, S., Maurer, D., Pambakian, A. L. M., & Kennard, C. (2000). The oculomotor distractor effect in normal and hemianopic vision. *Proceedings of the Royal Society of London Series B-Biological Sciences, 267*(1442), 431-438.

Warren, M. (2009). Pilot Study on Activities of Daily Living Limitations in Adults With Hemianopsia. *American Journal of Occupational Therapy, 63*(5), 626-633.

Warrington, E. K. (1962). Completion of Visual Forms Across Hemianopic Field Defects. *Journal of Neurology Neurosurgery and Psychiatry, 25*(3), 208-217.

Warrington, E. K., & James, M. (1991). *The Visual Object and Space battery*. Bury St. Edmunds, England: Thames Valley Test Company.

Watanabe, K., Shinoda, K., Kimura, I., Mashima, Y., Oguchi, Y., & Ohde, H. (2007). Discordance between subjective perimetric visual fields and objective multifocal visual evoked potential-determined visual fields in patients with hemianopsia. *American Journal of Ophthalmology, 143*(2), 295-304.

Webster, J. S., Jones, S., Blanton, P., Gross, R., Beissel, G. F., & Wofford, J. D. (1984). Visual Scanning Training with Stroke Patients. *Behavior Therapy, 15*(2), 129-143.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale – Third Edition*. San Antonio: The Psychological Corporation.

Weil, A. A., & Nosik, W. A. (1952). Photic Stimulation in Hemianopsia. *Electroencephalography and Clinical Neurophysiology, 4*(2), 219-222.

Wessinger, C. M., Fendrich, R., & Gazzaniga, M. S. (1999). Variability of residual vision in hemianopic subjects. *Restorative Neurology and Neuroscience, 15*(2-3), 243-253.

Wildberger, H. G. H., Vanlith, G. H. M., Wijngaarde, R., & Mak, G. T. M. (1976). Visually Evoked Cortical Potentials in Evaluation of Homonymous and Bitemporal Visual-Field Defects. *British Journal of Ophthalmology, 60*(4), 273-278.

Williams, D., & Gassel, M. M. (1962). Visual Function in Patients with Homonymous Hemianopia .1. Visual Fields. *Brain, 85*(2), 175-250.

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (1996). *Behavioural assessment of the dysexecutive syndrome*. Bury St Edmunds, UK: Harcourt Assessment.

Withaar, F. K. (2000). *Divided Attention and Driving: The Effects of Aging and Brain Injury*. Groningen: University of Groningen.

Wohl, T. A., Kattah, J. C., Kolsky, M. P., Alper, M. G., & Horton, J. C. (1991). Hemianopia from Occipital Lobe Abscess After Dental-Care. *American Journal of Ophthalmology, 112*(6), 689-694.

Wood, J. M., McGwin, G., Jr., Elgin, J., Vaphiades, M. S., Braswell, R. A., DeCarlo, D. K., . . . Owsley, C. (2009). On-Road Driving Performance by Persons with Hemianopia and Quadrantanopia. *Investigative Ophthalmology & Visual Science, 50*(2), 577-585.

Wood, J. M., McGwin, G., Jr., Elgin, J., Vaphiades, M. S., Braswell, R. A., DeCarlo, D. K., . . . Owsley, C. (2011). Hemianopic and Quadrantanopic Field Loss, Eye and Head Movements, and Driving. *Investigative Ophthalmology & Visual Science, 52*(3), 1220-1225.

World Health Organization. (2001). *International Classification of Functioning, Disability and Health Short version*. Geneva: WHO.

Younge, B. R. (1976). Midline Tilting between Seeing and Non-Seeing Areas in Hemianopia. *Mayo Clinic Proceedings, 51*(9), 562-568.

Zangemeister, W. H., Meienberg, O., Stark, L., & Hoyt, W. F. (1982). Eye-Head Coordination in Homonymous Hemianopia. *Journal of Neurology, 226*(4), 243-254.

Zangemeister, W. H., Oechsner, U., & Freksa, C. (1995). Short-Term Adaptation of Eye-Movements in Patients with Visual Hemifield Defects Indicates High-Level Control of Human Scanpath. *Optometry and Vision Science, 72*(7), 467-477.

Zhang, X., Kedar, S., Lynn, M. J., Newman, N. J., & Biousse, V. (2006a). Homonymous hemianopias - Clinical-anatomic correlations in 904 cases. *Neurology, 66*(6), 906-910.

Zhang, X., Kedar, S., Lynn, M. J., Newman, N. J., & Biousse, V. (2006b). Natural history of homonymous hemianopia. *Neurology, 66*(6), 901-905.

Zhang, X., Kedar, S., Lynn, M. J., Newman, N. J., & Biousse, V. (2006c). Homonymous hemianopia in stroke. *Journal of Neuro-Ophthalmology, 26*(3), 180-183.

Zihl, J. (1995a). Eye-Movement Patterns in Hemianopic Dyslexia. *Brain, 118*, 891-912.

Zihl, J. (1995b). Visual Scanning Behavior in Patients with Homonymous Hemianopia. *Neuropsychologia, 33*(3), 287-303.

Zihl, J. (1999). Oculomotor scanning performance in subjects with homonymous visual field disorders. *Visual Impairment Research, 1*(1), 23-31.

Zihl, J. (2011). *Rehabilitation of Visual Disorders After Brain Injury* (2nd ed.). UK: East Sussex: Pychology Press.

Zihl, J., Krischer, C., & Meissen, R. (1984). Hemianopic Dyslexia and its Treatment. *Nervenarzt, 55*(6), 317-323.

Zihl, J., Saemann, P., Schenk, T., Schuett, S., & Dauner, R. (2009). On the origin of line bisection error in hemianopia. *Neuropsychologia, 47*(12), 2417-2426.

Zihl, J., & Von Cramon, D. (1985). Visual-Field Recovery from Scotoma in Patients with Postgeniculate Damage - a Review of 55 Cases. *Brain, 108*(JUN), 335-365.

Zihl, J., Von Cramon, D., Brinkmann, R., & Backmund, H. (1977). Course and Prognosis of Scotomas in Patients with Cerebrovascular Disorders. *Nervenarzt, 48*(4), 219-224.

Summary

This dissertation describes the results of a study on homonymous visual field defects (HVFD). A HVFD is a loss in the visual field contralateral to postchiasmatic brain damage. Since only part of the visual field is perceived in case of HVFD, a complete overview of the surroundings is less easily obtained. This may lead to difficulties when moving around (i.e., walking, cycling, driving a car, etc.). If mobility is restricted, this might lead to social isolation, depression, and decreased quality of life. Therefore, it is highly important that effective and evidence-based rehabilitation programs are available that aim to minimize the effects of the HVFD in daily living. The studies described in this thesis focus on the consequences of having HVFD for everyday life, and more specifically, for mobility-related activities and participation. A substantial part of the thesis focusses on the effects of the InSight-Hemianopia Compensatory Scanning Training (IH-CST). The aim of this thesis is to contribute to more effective assessments and rehabilitation programs for people with HVFD, with the ultimate goal of improving mobility-related activities, participation in society and quality of life.

The thesis starts with a general introduction providing crucial background information on HVFD and opportunities for rehabilitation (**chapter 1**). This is followed by a chapter that describes the design and setup of our study (**chapter 2**) and that includes an introduction of the IH-CST.

In order to get an overview of the previous research on which the present study builds, a review of the literature was performed. **Chapter 3** summarizes 221 scientific publications on HVFD in terms of the variables that were examined and the factors that were found to influence functioning of HVFD patients or treatment effects. The International Classification of Functioning, Disability, and Health (ICF) was used to classify all the variables described in the publications. It was found that previous studies mainly focused on body functions, such as lesion location, etiology, visual functions, and neuropsychological functions. Activities and participation in daily life were not frequently discussed in the existing literature. The scientific findings are therefore hard to relate to the impact of having HVFD on functioning in daily life. The review concludes that previous research provided insufficient information on the difficulties experienced by patients with HVFD in daily life that should be targeted by rehabilitation programs. It is unknown which rehabilitation programs effectively improve functioning in everyday life. Furthermore, the existing literature provided insufficient information on potential predictors of future functioning of patients and the effects of specific training programs.

The thesis proceeds with the results of the empirical study, in which 54 participants with HVFD were examined. These participants had minimal comorbidities and the HVFD existed for at least five months. **Chapter 4** is devoted to the difficulties that these participants reported to experience in daily life because of the HVFD. The reported difficulties were categorized by linking the items from the questionnaires to the ICF. It was found that younger participants reported a wider range of activities to be difficult because of the HVFD. Younger participants were also less satisfied with their ability to travel independently than older participants. Furthermore, women experienced difficulties in a wider range of activities than men. As expected based on previous studies, difficulties with reading, orientation, and mobility-related activities were frequently mentioned. Surprisingly, the participants frequently reported a number of problems that did not seem directly related to missing portions of the visual field

and that had not been related to HVFD before. These problems included disturbed light sensitivity, color perception, and depth perception. Other frequently reported difficulties were related to recreation and leisure activities, negative feelings and thoughts, and feelings of decreased independence. These complaints once more stress the need for effective rehabilitation programs.

An activity significantly contributing to independent mobility is car driving. A subgroup of 26 participants took part in an official on-road test of practical fitness to drive by the Dutch driver's licensing authority (CBR: Centraal Bureau Rijvaardigheidsbewijzen). It was examined how driving performance was affected by HVFD and which participant characteristics were related to driving performance. The results are presented in **Chapter 5**. It was found that spontaneous compensation for the HVFD while driving a car was insufficient for 12 participants. Not only impairments in viewing behavior, but also in making tactical choices and operational handling of the car were observed. Aspects of driving that were most frequently reported to be not sufficient were steering stability, speed adaptation, and anticipating environmental changes. The results also indicated, however, that part of the patients with HVFD were able to compensate for the HVFD effectively and were judged to be fit to drive. This illustrates the wide variability in performance among patients with HVFD. Visual scanning and operational handling of the car were found to be more impaired with longer time not driven. A larger intact visual field was related to better driving performance. However, no cut-off point for visual field size was found below which all participants were unfit to drive. This shows that decisions on practical fitness to drive cannot be solely based on visual field size within the group of patients with HVFD. Chapter 5 concludes with recommendations for training driving performance.

Chapter 6 and 7 present the results of the randomized controlled trial (RCT) that examined the effects of a recently developed training program. The aim of the IH-CST is to teach patients to apply a systematic scanning strategy in order to compensate for the HVFD during mobility-related activities. The ultimate goal is to improve participation in society and vision-related quality of life. **Chapter 6** starts with a summary of the CST programs that have been described in the literature. An elaborate description of the IH-CST and the assessments to measure training effect are provided, followed by presentation of the results. Performance of participants with HVFD on mobility-related measures before onset of training was compared to performance of 25 healthy control participants. The results indicate that patients with HVFD needed significantly more time to detect peripheral stimuli and have more difficulty to avoid obstacles while walking, especially when performing a secondary task simultaneously. The effects of IH-CST were studied by comparing performance of the patients with HVFD before and after training with performance of patients in a waiting list control group. Specific effects of training were found on mobility-related activities and participation. Especially detection of peripheral stimuli and obstacle avoidance in mobility situations improved, while simultaneously performed tasks were not affected, or even improved as well. No evidence was found for an effect of IH-CST on visual functions (e.g., visual field size), nor on reading or visual search. This suggested that different scanning strategies are helpful for different types of activities. Detecting peripheral stimuli, which is important during mobility-related activities, was found to improve after practicing the wide, horizontal scanning strategy from the IH-CST.

Searching for a specific target among distracting information, which is important when searching for your keys for example, did not improve and appears to require a different type of scanning.

Chapter 7 presents the within-group training effects in an extended patient group. The results provide further support for the specific effects of the IH-CST. Performance on both subjective and objective mobility-related measures improved after training, while no evidence was found for improvement in visual functions (including visual fields), reading, and visual search. Self-reported improvement did not correlate with improvement in objective mobility performance. According to the participants, positive effects were still present six to ten months after training. The chapter also describes to what extent performance of the patients after training approached the level of performance of the healthy control group. Although the IH-CST improved visual performance in mobility-related tests, the patient group still performed worse on most parameters after following the training in comparison to the healthy control group. The last part of the results section discusses whether it can be predicted beforehand which patients benefit from IH-CST most. A recurring finding for both the subjective and the objective measures was that patients who performed worse before onset of training, showed more improvement after training. No demographic characteristics, variables related to the visual disorder, and neuropsychological test results were found to predict the size of training effect, although some evidence was found for more improvement in patients with a left-sided HVFD than in patients with a right-sided HFVD. The chapter concludes with discussing the clinical implications of the findings.

Chapter 8 provides a general discussion of the preceding chapters. The main findings regarding four important issues are recapitulated: the focus of previous studies on HVFD, the functioning of patients with HVFD, the effects of training, and the factors that influence functioning or training effects. Implications for clinical practice and suggestions for future research are discussed.

Abbreviations

ARV: area of residual vision
CBR: Centraal Bureau Rijvaardigheidsbewijzen (Dutch driver's licensing authority)
CST: compensatory scanning training
CVD: cerebral visual disorders questionnaire
Dots-correct-all, dots-correct-few, dots-correct-many: proportion of correct responses for counting dot patterns overall, for counting patterns with few dots, and for counting patterns with many dots, respectively
Dots-RT-all, dots-RT-few, dots-RT-many: reaction times for counting dot patterns overall, for counting patterns with few dots, and for counting patterns with many dots, respectively
DPR: professional driving expert
DSR: dual-to-single-task-ratio
DSR-all, DSR-blind, DSR-seeing: dual-to-single-task-ratio regarding reaction times for peripheral stimuli in Tracking Task overall, for stimuli on the blind side, and for stimuli on the seeing side, respectively
FFS: Functional Field Score
FU: follow-up assessment
GECKO: Groningen Edge Contrast Chart
GLM: general linear model
GLOB: global subscale of TRIP checklist
HEALTHY: healthy control group
HH: homonymous hemianopia
HVFD: homonymous visual field defect
ICF: international classification of functioning, disability, and health
IH: InZicht Hemianopsie
IH-CST: Insight-Hemianopia compensatory scanning training
IMQ: independent mobility questionnaire
LHH: left-sided hemianopia
MMSE: Mini Mental State Examination
NEI-VFQ-25: National Eye Institute - visual functioning questionnaire
OPER: operational subscale of TRIP checklist
P-training: patient training group
P-waiting: patient waiting list control group
Par-err: total number of errors on parallel search task
Par-omis: number of target omissions on parallel search task
Par-RT-all, par-RT-target, par-RT-notarget: reaction times in parallel search task overall, for trials containing a target, and for trials not containing a target, respectively
PPWS: percentage preferred walking speed
RCT: randomized controlled trial
RHH: right-sided hemianopia
SD: standard deviation
SDLP: standard deviation of lateral position
Ser-err: total number of errors on serial search task
Ser-omis: number of target omissions on serial search task

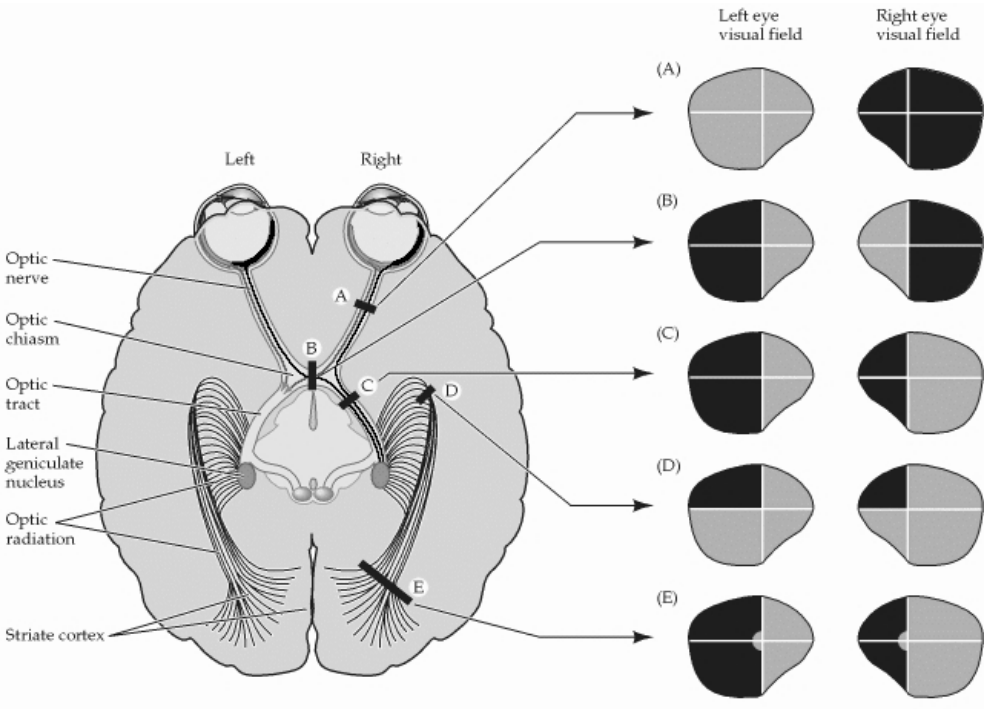
Ser-RT-all, ser-RT-target, ser-RT-notarget: reaction times in serial search task overall, for trials containing a target, and for trials not containing a target, respectively
SPSS: statistical package for the social sciences
T1, T2, T3: first, second and third assessment, respectively
T-pre, T-post: assessment before and after training, respectively
TACT: tactical subscale of TRIP checklist
TRIP: test ride for investigating practical fitness to drive
TT-err: number of faulty responses on Tracking Task
TT-omis: number of omissions on Tracking Task
TT-RT-all, TT-RT-blind, TT-RT-seeing: reaction times for peripheral stimuli in Tracking Task overall, for stimuli on the blind side, and for stimuli on the seeing side, respectively
VFD: visual field defect
VIS: visual subscale of TRIP checklist
VOD: visual acuity right eye
VOS: visual acuity left eye

Nederlandse samenvatting

HOOFDSTUK 1: INLEIDING

Een van de mogelijke gevolgen van hersenschade is uitval van het gezichtsveld (het gebied dat we zien wanneer we naar een vast punt kijken). Wanneer iemand blind is voor de linker- of rechterhelft van het gezichtsveld, spreken we van **hemianopsie**. Om dit beter te begrijpen, volgt eerst een korte uitleg van het visuele hersensysteem aan de hand van Figuur 12.1.

Visuele informatie komt binnen in de ogen en wordt door de zenuwcellen van het netvlies omgezet in signalen. Deze signalen worden verder getransporteerd door zenuwen die van het oog naar de visuele hersenschors achter in het hoofd lopen. Een deel van deze zenuwbanen kruist halverwege, in het zogenaamde optisch chiasma (zie Figuur 12.1). Dit zorgt ervoor dat informatie uit de linkerhelft van het gezichtsveld in de rechter visuele hersenschors wordt verwerkt en informatie van de rechterhelft van het gezichtsveld in de linker visuele hersenschors. Wanneer er dus in de linkerhelft van de hersenen schade aan het visuele systeem achter het optisch chiasma optreedt, geeft dit uitval in het rechterdeel van het gezichtsveld en andersom. Deze uitval is homoniem, wat betekent dat voor beide ogen hetzelfde gebied van het zicht is uitgevallen. Afhankelijk van de locatie en grootte van de hersenschade, kan van het gezichtsveld de linker- of rechterhelft (hemianopsie), een kwart (kwadrantanopsie) of een klein 'eilandje' (scotoom) zijn weggevallen (vele tussenvormen



Figuur 12.1. Weergave van de belangrijkste visuele banen van de ogen naar de visuele hersenschors (striate cortex). De zwarte delen in de figuren rechts staan voor de uitgevallen delen van het zicht ten gevolge van schade op verschillende locaties (A-E). Afgebeeld met toestemming (Purves et al., 2001).

Omdat met iedere oogopslag slechts een deel van het gezichtsveld wordt waargenomen, hebben mensen met gezichtsvelduitval minder snel een goed overzicht van de omgeving. Door de ogen te bewegen richting de blinde zijde, komt nieuwe informatie in beeld. Dit wordt echter vaak onvoldoende gedaan, waarschijnlijk omdat er niets is wat de aandacht trekt aan de blinde kant. Dit kan met name tot problemen leiden voor de mobiliteit (lopen, fietsen, autorijden, etc.), waarbij een volledig overzicht en waarschuwingssignalen van links en rechts erg belangrijk zijn.

Gelukkig worden steeds meer compensatietrainingen ontwikkeld, waarbij mensen door middel van bepaalde aanpassingen beter met de gezichtsvelduitval leren omgaan. Echter zijn deze trainingen nog onvoldoende wetenschappelijke onderbouwd. Een groot deel van dit proefschrift gaat over de effecten van een dergelijke training op het dagelijks leven, met name op de mobiliteit. Verder wordt beschreven tot welke dagelijkse problemen gezichtsvelduitval leidt en welke factoren ervoor zorgen dat iemand minder hinder van de uitval ondervindt of dat iemand meer van training profiteert dan anderen.

Het doel van dit proefschrift is bij te dragen aan betere diagnostiek en trainingsmethoden voor mensen met gezichtsvelduitval, met als uiteindelijke doel om de mobiliteit, deelname aan de maatschappij en kwaliteit van leven te verbeteren.

HOOFDSTUK 2: ONDERZOEKSOPZET

Dit proefschrift beschrijft de resultaten van een onderzoek naar homonieme gezichtsvelduitval. Dit onderzoek is uitgevoerd door de Rijksuniversiteit Groningen, in nauwe samenwerking met Koninklijke Visio en Bartiméus, de twee grootste expertisecentra voor slechtziende en blinde mensen, en met het Centraal Bureau Rijvaardigheidsbewijzen (CBR). Het onderzoek, bekend onder de projectnaam InZicht Hemianopsie, bestond uit een literatuuronderzoek en een patiëntonderzoek.

Aan het patiëntonderzoek hebben 54 mensen met homonieme gezichtsvelduitval (in het vervolg aangeduid met hemianopsie) deelgenomen. Daarnaast vormden 25 mensen zonder hersenschade en met goed zicht de zogenaamde gezonde controlegroep. De mensen met hemianopsie volgden bij Visio of Bartiméus een training, welke in hoofdstuk 2 wordt geïntroduceerd en in hoofdstuk 6 verder wordt uitgelegd. Het gaat om de IH-CST (InZicht-Hemianopsie Compensatoire Scanning Training), beter bekend als de IH-training. Kort samengevat leren mensen bij deze training een kijkstrategie toe te passen met als doel om sneller een beter overzicht van de omgeving te krijgen en daardoor minder hinder van de hemianopsie te hebben wanneer ze zich voortbewegen.

Het onderzoek is opgezet als een randomised controlled trial (RCT). In dit geval betekent dit dat het effect van het volgen van training afgezet is tegen het effect van geen training ontvangen, de zogenaamde wachtlijstperiode. Voor dit doel zijn de deelnemers met hemianopsie verdeeld in twee groepen. Bij de trainingsgroep heeft voor en na de training een effectmeting plaatsgevonden (meetmoment T1 en T2). De wachtlijstgroep stond tussen deze twee meetmomenten op de wachtlijst. Na T2 hebben ook zij de training gevolgd, waarna een derde meetmoment (T3) plaatsvond. Door het verschil tussen T1 en T2 in de trainingsgroep te vergelijken met het verschil tussen T1 en T2 in de wachtlijstgroep, kan aangetoond worden welke effecten toe te schrijven zijn aan de training en welke aan hertesteffecten of spontane

verbetering. Beide groepen hebben zes tot tien maanden na afloop van de training aan een zogenaamde follow-upmeting deelgenomen, bedoeld om het langetermijneffect van de training te onderzoeken. De gezonde controlegroep heeft aan één meetmoment deelgenomen en heeft uiteraard geen training gevolgd. In hoofdstuk 2 wordt beschreven welke tests op de meetmomenten zijn afgenomen.

HOOFDSTUK 3: LITERATUURONDERZOEK

Om een overzicht te krijgen van het eerdere onderzoek waar huidig onderzoek op voortbouwt, is een literatuuronderzoek gedaan. De zoektocht naar de beschikbare literatuur over onderzoek bij hemianopsiepatiënten leverde 221 wetenschappelijke artikelen op. In 180 van deze artikelen werd het functioneren van hemianopsiepatiënten beschreven die (nog) geen training hadden ontvangen. Het effect van compensatietraining werd in 29 artikelen genoemd en in 31 artikelen kwam het effect van restoratietraining (training gericht op herstel van het gezichtsveld) aan bod.

Voor elk artikel werd systematisch onderzocht welke variabelen werden beschreven. Al deze variabelen werden geclassificeerd aan de hand van het ICF-model (International Classification of Functioning, Disability and Health). Zo werd bijvoorbeeld de zijde van de gezichtsvelduitval ingedeeld bij de lichaamsfuncties, de leessnelheid bij activiteiten, terugkeer naar betaald werk bij participatie en leeftijd bij de persoonlijke factoren. Hierbij viel op dat variabelen op activiteitenniveau vaker meegenomen werden in onderzoeken naar het effect van compensatietraining dan in andere onderzoeken (in 76% van de onderzoeken naar compensatietraining tegen 35% van de onderzoeken naar restoratietraining en 28% van de onderzoeken naar het functioneren zonder training). Daarentegen werden maten voor participatie vaker meegenomen in onderzoek naar restoratietraining (26% tegen 10% van de onderzoeken naar compensatietraining en 9% van de onderzoeken naar functioneren zonder training), hoewel de participatie meestal maar erg beperkt werd onderzocht. Er werd bijvoorbeeld alleen gevraagd naar hervatten van hobby's of terugkeer naar werk. Waar de revalidatie in de klinische praktijk zich met name richt op het herstel van activiteiten en participatie, worden de effecten van deze revalidatieprogramma's dus lang niet altijd op activiteiten- en participatieniveau wetenschappelijk onderzocht. Hier lijkt sprake van een gat tussen de wetenschap en de praktijk.

Verder werd voor elk artikel bekeken welke variabelen onderzocht werden op hun onderlinge samenhang. Dit zijn de zogenaamde 'voorspellers'. Persoonlijke factoren, zoals leeftijd, geslacht en tijd sinds ontstaan van de hemianopsie, werden het vaakst onderzocht op hun verband met andere maten. Hoewel het aannemelijk is dat het uitvoeren van activiteiten en de participatie in de maatschappij voor een groot deel beïnvloed wordt door omgevingsfactoren, geeft de wetenschappelijke literatuur tot op heden geen enkele informatie over de mogelijke invloed van omgevingsfactoren.

Hoofdstuk 3 wordt vervolgd met informatie over de specifieke voorspellers die in de 221 artikelen genoemd zijn. Zo werd bijvoorbeeld gevonden dat het gezichtsveld vaker (gedeeltelijk) herstelt wanneer tussen het velddefect en het intacte gezichtsveld een gebied zit met enige sparing (zogenaamde relatieve uitval), dan wanneer dit niet het geval is. In geval van een complete hemianopsie (volledige helft uitgevallen) is de kans op herstel van het

gezichtsveld kleiner dan bij een incomplete hemianopsie of kwadrantanopsie. Voor compensatietraining werd gevonden dat mensen die tijdens de training meer en grotere hoofdbewegingen maken meer trainingssessies nodig hebben om het visuele overzicht te vergroten. Hoewel sommige onderzoeken geen invloed van leeftijd op het effect van compensatietraining hebben gevonden, zijn er enige aanwijzingen dat oudere mensen meer profijt hebben van training bij het uitvoeren van dagelijkse activiteiten. Er zijn tot op heden geen aanwijzingen gevonden dat het effect van compensatietraining anders is voor mannen dan voor vrouwen.

Deze review toont aan dat er nog veel onbekend is over het effect van compensatietraining op dagelijkse activiteiten en participatie in de maatschappij. Er zijn veel verschillende trainingsprotocollen onderzocht en vaak met verschillende uitkomstmaten, wat vergelijken moeilijk maakt. Ook is er nog onvoldoende bekend over de factoren die het effect van training kunnen voorspellen. Kortom, op dit moment kan op basis van de beschikbare wetenschappelijke literatuur nog niet goed voorspeld worden welke training voor welke patiënt het meeste oplevert in het dagelijks leven.

HOOFDSTUK 4: GEVOLGEN VOOR HET DAGELIJKS LEVEN

In de hoofdstukken 4 t/m 7 worden de uitkomsten beschreven van het patiëntonderzoek. Hoofdstuk 4 behandelt de moeilijkheden die mensen met hemianopsie ervaren in het dagelijks leven. Voor zover ons bekend, waren deze ervaren moeilijkheden nog niet eerder systematisch onderzocht. Voorafgaand aan de training werd de deelnemers allereerst de open vraag gesteld voor welke problemen de gezichtsvelduitval in het dagelijks leven zorgde. Vervolgens werden drie gestandaardiseerde vragenlijsten ingevuld, waarbij gevraagd werd naar de ervaren moeite met allerlei situaties (NEI-VFQ-25: National Eye Institute Visual Functioning Questionnaire, VOM: Vragenlijst Onafhankelijke Mobiliteit, CVS: Cerebrale Visuele Stoornissen vragenlijst). Omdat de vragenlijsten samen in totaal 102 vragen bevatten, nog afgezien van alle gegeven antwoorden op de open vraag, was het nodig om de vragen en antwoorden in overzichtelijke subgroepen in te delen. Er is voor gekozen om de onderdelen van een veelgebruikt classificatiemodel, namelijk het ICF-model, als subgroepen aan te houden. Alle antwoorden op de open vraag en alle items van de gestandaardiseerde vragenlijsten werden gekoppeld aan dit ICF-model. De koppeling van de vragenlijsten aan het ICF-model is terug te vinden in een tabel en kan gebruikt worden voor vervolgonderzoek.

Open vraag: Voor elk onderdeel van het ICF-model werd geteld hoeveel mensen ten minste één probleem op dit onderdeel spontaan rapporteerden. Veel gerapporteerde klachten waren moeite met het tijdig zien of ontwijken van mensen of objecten vanwege onvoldoende overzicht en andere mobiliteitsgerelateerde problemen bij lopen, fietsen of autorijden. Ook het omstoten van voorwerpen op tafel en moeite met lezen, televisie kijken, computergebruik, winkelen en uitvoeren van hobby's werden veel genoemd. Verder werden vermoeidheid en gevoelens van frustratie, irritatie, onzekerheid, angst en spanning veel ervaren. Wat betreft de omgevingsfactoren werden met name onbekende, drukke of donkere plaatsen als moeilijk ervaren.

Gestandaardiseerde vragenlijsten: Voor elk onderdeel van het ICF-model werd geteld hoeveel mensen ten minste één vraag behorende bij dit onderdeel beantwoord hebben met

'dit gaat moeizaam' of een vergelijkbaar antwoord. De resultaten bevestigen opnieuw dat hemianopsie vaak leidt tot moeite met het vinden van voorwerpen, lezen en mobiliteit. Ook werd gevonden dat hemianopsie een grote impact kan hebben op de participatie in de maatschappij. Veel deelnemers rapporteerden namelijk moeite te hebben met het uitvoeren van hobby's en deelname aan sport en sociale evenementen. Ook rapporteerden veel deelnemers afhankelijk te zijn van anderen en negatieve gevoelens en gedachten te hebben vanwege de hemianopsie.

Een grote meerderheid van de deelnemers (94%) gaf aan klachten te hebben op het gebied van gevoeligheid voor licht. Ongeveer de helft (52%) van de deelnemers rapporteerde dat alles donkerder lijkt of dat meer licht nodig is om te kunnen lezen, terwijl ook door de helft (54%) van de deelnemers werd genoemd dat ze sneller verblind werden door fel licht dan voorheen. Hoewel deze twee klachten op het eerste gezicht tegenstrijdig lijken, werden beide klachten vaak door dezelfde mensen genoemd. Moeite met lichtovergangen werd ook door het meerendeel (56%) van de deelnemers genoemd. Niet eerder werden de klachten op het gebied van lichtgevoeligheid bij mensen met hemianopsie onderzocht. Dat kleuren niet meer zo helder lijken als voorheen, werd door 21% van de deelnemers bevestigd. Ook moeite met het inschatten van de hoogte van de volgende traptrede tijdens traplopen werd door 21% genoemd.

Jongere deelnemers en vrouwen rapporteerden moeilijkheden op meer verschillende gebieden dan respectievelijk de oudere deelnemers en mannen. Mogelijk waren de jongere deelnemers voor het ontstaan van de hemianopsie op bepaalde gebieden actiever dan de oudere deelnemers, waardoor een beperking door de hemianopsie een grotere impact heeft. Er werden geen aanwijzingen gevonden voor een effect van tijd sinds ontstaan van de hemianopsie, zijde van de gezichtsvelduitval (links of rechts) of type gezichtsvelduitval (hemianopsie vs. kwadrantanopsie) op het aantal gebieden waarop mensen klachten rapporteerden.

Samenvattend heeft deze systematische verkenning van de klachten van mensen met hemianopsie laten zien dat velen van hen moeite met lichtgevoeligheid, dieptezien en kleurenzien ervaren. Mogelijk hangen deze klachten niet specifiek samen met hemianopsie, maar zijn ze een meer algemeen gevolg van de onderliggende hersenschade. Toch is het goed dat we ons bewust zijn dat deze klachten door een groot deel van de mensen met hemianopsie ervaren worden, zodat we hier bij de diagnostiek en revalidatie aandacht voor hebben. Verder is het goed om bij het inventariseren van de individuele klachten zowel open vragen te stellen, als gestandaardiseerde vragenlijsten af te nemen. In huidig onderzoek leverden deze namelijk aanvullende informatie op.

HOOFDSTUK 5: AUTORIJDEN

Van de 54 onderzoeksdeelnemers met hemianopsie namen 26 deelnemers tevens deel aan het officiële herkeuringstraject voor de rijgeschiktheid bij het CBR. Deze mensen hadden Visio gevraagd om hulp op het gebied van autorijden en voldeden aan de Nederlandse eisen voor de medische rijgeschiktheid. In de Nederlandse regeling wordt namelijk gesteld dat mensen die een gezichtsveld hebben dat horizontaal gemeten tussen de 90 en 120 graden is en die verder geen bijkomende stoornissen hebben, middels een test praktische rijgeschiktheid mogen

aantonen of ze voldoende in staat zijn om voor de gezichtsvelduitval te compenseren tijdens het autorijden.

In hoofdstuk 5 wordt beschreven hoe de rijgeschiktheid werd beoordeeld door een deskundige praktische rijgeschiktheid (DPR) tijdens het rijden op de weg. Veertien deelnemers (54%) werden praktisch rijgeschikt bevonden. De deelnemers die niet rijgeschikt bevonden werden, scoorden vooral laag op het kijkgedrag, maar ook op het maken van bepaalde tactische keuzes (met name het kiezen van de juiste snelheid) en het uitvoeren van operationele handelingen tijdens het rijden (met name de stuurvastheid). Omdat het zicht de belangrijkste bron van input is tijdens autorijden, moet iemand met gezichtsvelduitval meer moeite doen om alle nodige informatie te verkrijgen. Mogelijk zorgt dit voor tijdsdruk en beperkt dit de aandacht die beschikbaar is voor andere zaken, zoals het maken van de juiste keuzes en het uitvoeren van alle deelhandelingen tijdens het autorijden. Voor drie mensen die niet rijgeschikt beoordeeld waren, werd in het rapport expliciet vermeld dat het kijken naar de blinde kant ervoor zorgde dat het rijgedrag en de positie op de weg onvoldoende waren. Voor alle 14 deelnemers die rijgeschikt bevonden werden, was het kijkgedrag beoordeeld als voldoende en hinderde het aangepaste kijkgedrag hen niet in de andere aspecten van het autorijden.

Hoewel een kleiner gezichtsveld samen ging met lagere scores voor het kijkgedrag en het uitvoeren van deelhandelingen, bleek de grootte van het gezichtsveld de geslaagde deelnemers niet van de gezakte deelnemers te kunnen onderscheiden. Er was geen waarde voor de grootte van het gezichtsveld waar beneden alle deelnemers zakten. Verder bleek dat hoe langer de deelnemer niet had gereden, hoe slechter de beoordeling van het kijkgedrag en de operationele handelingen, terwijl geen effect op de tactische keuzes werd gevonden. Er werden geen effecten gevonden van leeftijd, geslacht of aantal jaar rijervaring op het rijgedrag.

Deze resultaten geven aan dat een deel van de mensen met hemianopsie goed in staat is om voor het tekort aan visuele input te compenseren. Bij training gericht op het verbeteren van de praktische rijgeschiktheid voor mensen met hemianopsie zou aandacht moeten zijn voor het toepassen van de juiste kijkstrategieën zonder dat dit de andere aspecten van het rijden negatief beïnvloedt. Ook worden rijlessen geadviseerd, mede vanwege de bevinding dat bepaalde aspecten van het rijden lager beoordeeld werden naarmate mensen langer niet gereden hadden. Tijdens deze rijlessen dient volgens de huidige bevindingen met name aandacht te zijn voor het kijkgedrag tijdens inhalen en voorbijgaan, de stuurvastheid, het kiezen van de juiste snelheid en het anticiperen op veranderingen in de omgeving.

HOOFDSTUK 6 EN 7: EFFECTEN VAN TRAINING

De resultaten van het onderzoek naar de effecten van de IH-training staan centraal in de hoofdstukken 6 en 7. Hoofdstuk 6 begint met een samenvatting van de compensatietrainingen die in de literatuur zijn beschreven. Dan volgt een uitgebreide beschrijving van de IH-training en van de tests die gedaan zijn om het trainingseffect te meten. Uit de resultaten blijkt dat de deelnemers met hemianopsie meer tijd nodig hadden om informatie aan de linker- en rechterzijde waar te nemen dan de gezonde controlegroep. Ook hadden ze meer moeite om obstakels te vermijden tijdens het lopen, vooral wanneer ze tegelijkertijd met een mentale opdracht bezig waren. De training gaf op deze taken een verbetering. Met name

mobiliteitsgerelateerde activiteiten en deelname aan de maatschappij verbeterden na training. De deelnemers ervaarden zelf dat ze na training minder hinder hadden van de hemianopsie tijdens het voortbewegen en dit werd ondersteund door de verbetering van de testprestaties. Informatie aan de blinde zijde werd sneller opgemerkt en dit ging niet ten koste van het waarnemen van informatie aan de intacte zijde en recht vooruit (d.w.z. geen overcompensatie) of van de aandacht voor andere taken die gelijktijdig uitgevoerd werden. Dit is een belangrijke bevinding, omdat het bij mobiliteit belangrijk is om zowel aandacht te hebben voor wat recht vooruit gebeurt en daarop te anticiperen, als informatie van links en rechts goed op te merken. Daarbij is het ook van belang dat er voldoende aandacht overblijft om bijvoorbeeld tijdens het lopen een gesprek met iemand te kunnen voeren of te kunnen reageren op onverwachte bewegingen van andere weggebruikers.

De grootte van de gezichtsvelduitval veranderde niet door de training. De verbetering in de waarneming tijdens het voortbewegen werd dus niet veroorzaakt door een verbetering in het gezichtsveld, maar door een verbetering in de manier van kijken. Er zijn geen aanwijzingen gevonden voor een effect van de training op lezen of zoeken. Dit geeft aan dat waarschijnlijk verschillende kijkstrategieën zinvol zijn voor verschillende typen taken. Het opmerken van informatie links en rechts, met name belangrijk tijdens het voortbewegen, verbeterde na training. Lezen en zoeken naar een voorwerp tussen afleidende voorwerpen, zoals zoeken naar een product in een winkelschap, verbeterden niet door de training en vereisen kennelijk een andere manier van kijken dan tijdens deze training geleerd werd.

Hoofdstuk 7 beschrijft de resultaten van aanvullende analyses. Er is opnieuw ondersteuning gevonden voor positieve effecten van de training op taken die met mobiliteit te maken hebben. Hoewel de ervaringen van de deelnemers en de testprestaties beide verbeterden door de training, hingen deze twee niet samen. Het is dus niet zo dat de mensen die de grootste verbetering lieten zien op de tests, ook de mensen zijn die zelf de meeste verbetering ervaarden. Ondanks de verbetering die de deelnemers met hemianopsie lieten zien, bereikten ze na training op de meeste tests niet het niveau van de gezonde controlegroep. Er kon op basis van persoonskenmerken, eigenschappen van het gezichtsveld of scores op neuropsychologische tests niet voorspeld worden hoe groot het effect van training was. Er zijn echter enige aanwijzingen dat het trainingseffect groter was voor mensen met een linkszijdige hemianopsie dan voor mensen met een rechtszijdige hemianopsie. De grootte van het trainingseffect hing vooral samen met het niveau voorafgaand aan de training. Mensen die vooraf slechter presteerden dan anderen, verbeterden over het algemeen meer door de training. De training lijkt langetermijneffecten te hebben. Zes tot tien maanden na afloop van de training gaven de deelnemers aan nog steeds de positieve effecten van de training te ervaren. Hoofdstuk 7 sluit af met het beschrijven van de betekenis van de resultaten voor de praktijk.

HOOFDSTUK 8: DISCUSSIE EN CONCLUSIE

Het laatste hoofdstuk brengt alle voorgaande hoofdstukken samen. Er worden adviezen gegeven over wanneer, hoe, bij welke mensen en bij welke hulpvragen de onderzochte trainingsmethode in te zetten; over de aspecten van de training die nog verder onderzocht moeten worden; over het meten en trainen van de rijgeschiktheid; over (vervolg)onderzoek

naar de gevolgen van hemianopsie; en over het gebruik van een classificatiemodel (ICF) in onderzoek en klinische praktijk.

Het onderzoek beschreven in dit proefschrift heeft bijgedragen aan onze kennis over de invloed van hemianopsie op het dagelijks leven en in het bijzonder op de mobiliteit. Een overzicht van de literatuur over hemianopsie is nu beschikbaar, welke als naslagwerk of als startpunt voor verder onderzoek gebruikt kan worden. Het patiëntonderzoek heeft geresulteerd in een overzicht van de klachten die hemianopsie in het dagelijks leven geeft, in kennis over de gevolgen van hemianopsie voor autorijden en in een wetenschappelijk onderbouwde trainingsmethode voor het verbeteren van de dagelijkse mobiliteit. Hiermee draagt het proefschrift bij aan optimaliseren van de diagnostiek en behandeling voor mensen met hemianopsie, met als uiteindelijke doel om de dagelijkse mobiliteit, deelname aan de maatschappij en kwaliteit van leven te verbeteren.

Dankwoord

Toen ik meteen na mijn afstuderen aan dit project mocht beginnen, had ik geen idee wat me te wachten stond. Met enige twijfel over mijn eigen kunnen, maar vol enthousiasme, ging ik het avontuur aan. Gelukkig stond ik er niet alleen voor en had ik veel mensen om mij heen die het traject een stuk makkelijker maakten.

Allereerst ben ik erg dankbaar voor de begeleiding die ik heb gehad van mijn (co)promotores. Wiebo Brouwer, Oliver Tucha, Joost Heutink en Bart Melis-Dankers, bedankt voor het vertrouwen dat jullie in mij stelden. Jullie hebben me veel vrijheid gegeven in het werk, maar voor hulp kon ik altijd bij jullie terecht. In het bijzonder wil ik Joost bedanken voor zijn dagelijkse begeleiding. Ik heb enorm veel van je geleerd, onder andere dat als je een vraag juist stelt, deze zichzelf vaak beantwoordt. Bedankt ook dat je me erop hebt gewezen dat ik fouten mag maken (uiteraard met mate) en dat fouten maken soms zelfs noodzakelijk is om verder te komen.

Hierbij wil ik ook de leden van de beoordelingscommissie, Georg Kerkhoff, Hans van der Steen en Joke Spikman, hartelijk danken. Ook ben ik de subsidieverstrekkers grote dank verschuldigd: ZonMw-InZicht, Koninklijke Visio en de Rijksuniversiteit Groningen. Hoofdstuk 5 kon alleen geschreven worden dankzij de medewerking van het CBR. In het bijzonder wil ik Ruud Bredewoud, Jos de Vries en de Deskundigen Praktische Rijgeschiktheid bedanken.

Mijn grote dank ook voor de ruim 100 medewerkers van Koninklijke Visio en Bartiméus die bij het project betrokken zijn geweest. Ondanks de nodige moeilijkheden die komen kijken bij het implementeren van een onderzoeksproject in een revalidatieinstelling is het dankzij jullie hulp gelukt om het project van de grond te krijgen.

Verder wil ik de betrokken medewerkers van de Rijksuniversiteit Groningen bedanken. Dankzij mijn collega's heb ik het onderzoek met plezier uitgevoerd op de afdeling Klinische en Ontwikkelingsneuropsychologie. In het bijzonder wil ik mijn mede-PhD-studenten bedanken. Ik heb jullie kunnen raadplegen voor werkgerelateerde en niet-werkgerelateerde zaken en heb veel met jullie gelachen. Grote dank ook aan de Instrumentatiedienst voor jullie hulp bij allerlei technische zaken, in het bijzonder aan Mark Span, Pieter Zandbergen, Eise Hoekstra en Jaap Ruiter. Ook wil ik Peter van Wolffelaar bedanken voor zijn werk aan de rijsimulator. Verder wil ik Jolanda Polling-Oosterloo en Josje de Roo bedanken voor hun hulp en advies bij allerlei zaken. Dank ook aan alle masterstudenten die geholpen hebben met de dataverzameling.

Uiteraard ben ik ook grote dank verschuldigd aan alle mensen die als 'proefpersoon' aan het onderzoek hebben deelgenomen. Zonder jullie was er geen onderzoek geweest. Jullie beweegredenen om aan het onderzoek deel te nemen waren erg inspirerend. Bedankt voor jullie inzet!

Elbrich Steegstra, bedankt voor het ontwerpen van de omslag van het proefschrift. Het was leuk om met je samen te werken. Ik hoop je snel weer te zien op de volgende Radijsjesdag.

Frans en Tineke, ik ben erg dankbaar voor jullie hulp als paranimfen, maar nog meer voor het feit dat ik jullie als broertje en zusje heb. Ik kan me geen betere broer en zus wensen. Bedankt heit en mem, ik weet dat ik altijd bij jullie terecht zal kunnen. Thuis zal altijd thuis blijven. Lieve oma, bedankt voor het bieden van een rustige plek om te schrijven. Ik heb veel effectieve uren bij u thuis gemaakt.

Daarnaast wil ik alle andere mensen bedanken die tijdens deze periode dichtbij mij stonden. Bedankt dat jullie me motiveerden om aan het werk te gaan en bedankt dat jullie me

op de nodige tijden van mijn werk hielden. Bij deze ook mijn excuses. Ik was niet altijd beschikbaar om bij de picknicktafelgesprekken aan te schuiven, mee te gaan stappen, film te kijken, etc., omdat ik aan de laptop gekluisterd zat. Ik hoop de komende tijd weer meer aandacht aan mijn omgeving te geven, die bestaat uit zoveel lieve mensen.

Publications and presentations

PUBLICATIONS

De Haan, G. A. Adviesrapport. Naar aanleiding van InZicht Hemianopsie, een onderzoeksproject naar het effect van de Compensatoire Scanningstraining (IH-CST) op de mobiliteit bij mensen met hemianopsie. Augustus 2013, uitgave Koninklijke Visio en Bartimeus.

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Tucha, O., & Brouwer, W. H. (2014). Spontaneous recovery and treatment effects in patients with homonymous visual field defects: a meta-analysis of existing literature in terms of the ICF framework. *Survey of Ophthalmology, 59*(1), 77-96.

De Haan, G. A., Melis-Dankers, B. J., Brouwer, W. H., Bredewoud R. A., Tucha, O., & Heutink, J. (2014). Car driving performance in hemianopia: an on-road driving study. *Investigative Ophthalmology & Visual Science, 55*, 6482-6489.

De Haan, G. A., Heutink, J., Melis-Dankers, B. J. M., Brouwer, W. H., & Tucha, O. (2015). Difficulties in daily life reported by patients with homonymous visual field defects. *Journal of Neuro-Ophthalmology, 35*, 259-264.

De Haan, G. A., Melis-Dankers, B. J., Brouwer, W. H., Tucha, O., & Heutink, J. (2015). The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: a randomized controlled trial. *PloS One, 10*(8), e0134459.

De Haan, G. A., Melis-Dankers, B. J., & Heutink, J. (2015). Autorijden met hemianopsie: mogelijkheden en kansen. *Tijdschrift voor Neuropsychologie, 10*(3), 198-209.

De Haan, G. A. (accepted for publication). Waarneming: 'Hemianopsie'. In Richtlijn Neuropsychologische Revalidatie: Niet-aangeboren Hersenletsel. Consortium Cognitieve Revalidatie.

De Haan, G. A., Melis-Dankers, B. J. M., Brouwer, W. H., Tucha, O., & Heutink, J. (in revision). The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: further support, predictive variables and follow-up. *PloS One.*

De Haan, G. A., Melis-Dankers, B. J. M., Brouwer, W. H., Tucha, O., & Heutink, J. (in revision). Hemianopsie: gevolgen voor het dagelijks leven en de effecten van compensatietraining. *Neuropraxis*.

PRESENTATIONS

International

- The effect of target speed on visual motion perception in a patient with akinetopsia. Posterpresentatie, Second Meeting of the Federation of the European Societies of Neuropsychology (ESN), Amsterdam, Nederland, 22 september 2010.
- Compensatory scanning training for hemianopia. Presentatie, Vision 2011: 10th International Conference on Low Vision, International Society for Low Vision Research and Rehabilitation (ISLRR), Kuala Lumpur, Maleisië, 20 februari 2011.
- Subjective complaints in patients suffering from hemianopia. Posterpresentatie, Conference of the International Neuropsychological Society (INS), Oslo, Noorwegen, 27 juni 2012.
- The effect of compensatory scanning training on mobility in hemianopia patients. Posterpresentatie en presentatie, 9th Conference of the Neuropsychological Rehabilitation Special Interest Group, Bergen, Noorwegen, 2 juli 2012.
- The effects of compensatory scanning training on mobility for hemianopia patients. Presentatie, International Conference on Traffic and Transport Psychology (ICTTP), Groningen, Nederland, 29 augustus 2012.
- The effect of compensatory scanning training on visual scanning in hemianopia patients. Posterpresentatie, European Conference on Visual Perception (ECVP), Alghero, Italië, 4 september 2012.
- Car driving performance in hemianopia patients: The Effect of Compensatory Scanning Training. Presentatie, 23rd World Congress of the International Traffic Medicine Association (ITMA), Hamburg, Duitsland, 19 mei 2013.
- Compensatory scanning training for hemianopia patients. Posterpresentatie, 10th Conference of the Neuropsychological Rehabilitation Special Interest Group, Maastricht, Nederland, 8 juli 2013.
- Compensatory scanning training for hemianopia patients. Posterpresentatie, Conference of the International Neuropsychological Society (INS), Amsterdam, Nederland, 10 juli 2013.
- Car driving performance in hemianopia patients: The Effect of Compensatory Scanning Training. Presentatie, Vision 2014: 11th International Conference on Low Vision, International Society for Low Vision Research and Rehabilitation (ISLRR), Melbourne, Australië, 31 maart 2014.
- The effects of compensatory scanning training on mobility – a randomized controlled trial. Presentatie, Vision 2014: 11th International Conference on Low Vision, International Society for Low Vision Research and Rehabilitation (ISLRR), Melbourne, Australië, 1 april 2014.
- Eye movements during visual scanning tasks in homonymous hemianopia and the effects of compensatory scanning training. Posterpresentatie, Vision 2014: 11th International Conference on Low Vision, International Society for Low Vision Research and Rehabilitation (ISLRR), Melbourne, Australië, 2 april 2014.
- Compensatory scanning training for patients with homonymous visual field defects: specificity of effects. Presentatie, 35th European Winter Conference on Brain Research – European Brain and Behaviour Society Conference (EWCBR-EBBS), Brides les Bains, Frankrijk, 12 maart 2015.
- Compensatory scanning training for patients with homonymous visual field defects: specificity of effects. Presentatie, Caledonian University Glasgow, Glasgow, Schotland, 23 september 2015.
- The effects of compensatory scanning training on mobility in patients with homonymous visual field defects: A randomized controlled Trial. Presentatie, European Conference on Low Vision, European Society for Low Vision Research and Rehabilitation (ESLRR), Oxford, Engeland, 25 september 2015.
- Car driving performance and the effect of compensatory scanning training in hemianopia patients. Posterpresentatie en presentatie, European Conference on Low Vision, European Society for Low Vision Research and Rehabilitation (ESLRR),Oxford, Engeland, 26 september 2015.

National

- InZicht Hemianopsie: Onderzoeksopzet. Presentatie, trainingsdagen InZicht Hemianopsie voor Koninklijke Visio en Bartiméus, Huizen, 21 september 2009.
- Onderzoek naar het effect van compensatoire scanning training op de mobiliteit bij mensen met homonieme gezichtsvelduitval. Posterpresentatie, Ontmoetingsdag InZicht (ZonMw), Ede, 6 november 2009.
- The effect of target speed on visual motion perception in a patient with akinetopsia. Posterpresentatie, Heymans Symposium, RUG, Groningen, 2 december 2009.
- Inzicht Hemianopsie: Effecten van compensatoire scanningstraining op de mobiliteit bij homonieme hemianopsie. Presentatie, Unit Meeting Neuropsychologie RUG/UMCG, Groningen, 26 januari 2010.
- Revalidatie bij homonieme hemianopsie. College, opleiding Psychologie, RUG, Groningen, 24 februari 2010.
- InZicht Hemianopsie. Presentatie, Koninklijke Visio, Rotterdam, 13 april 2010.
- InZicht Hemianopsie. Presentatie, Werkbijeenkomst onderzoek en implementatie voor projectleiders/onderzoekers bij InZicht (ZonMw), Den Haag, 2 juni 2010.
- The effect of target speed on visual motion perception in a patient with akinetopsia. Posterpresentatie, BCN symposium, RUG, Groningen, 1 juli 2010.
- InZicht Hemianopsie. Presentatie, Bartimeus, Doorn, 30 september 2010.
- InZicht Hemianopsie. Presentatie, Site Visit ZonMw-InZicht, Groningen, 18 oktober 2010.
- InZicht Hemianopsie. Presentatie, trainingsdagen InZicht Hemianopsie voor Koninklijke Visio en Bartiméus, Huizen, 17 november 2010.
- Scanningstraining bij hemianopsie: voorlopige resultaten. Presentatie, Unit Meeting Neuropsychologie RUG/UMCG, Groningen, 25 januari 2011.
- Compensatory scanning training for hemianopia. Presentatie, Research meeting Clinical and Developmental Neuropsychology, RUG, Groningen, 31 januari 2011.
- InZicht Hemianopsie. Presentatie, Congres Focus op Onderzoek, georganiseerd door Kennisplein Gehandicaptensector en ZonMw, Utrecht, 1 december 2011.
- Compensatory scanning training for hemianopia. Posterpresentatie, Heymans Symposium, RUG, Groningen, 25 januari 2012.
- Compensatory scanning training for hemianopia. Posterpresentatie, BCN Symposium, RUG, Groningen, 2 februari 2012.
- InZicht Hemianopsie. Presentatie, Symposium Hemianopsie, georganiseerd door Bartiméus, Baarn, 19 april 2012.
- InZicht Hemianopsie. Presentatie, Friese Oogheelkundige refereeravond (FOK), Beetsterzwaag, 24 mei 2012.
- Oogbewegingen bij homonieme hemianopsie. Presentatie, bijeenkomst Oogheelkundige Fysica, Zeist, 31 mei 2012.
- Autorijden met hemianopsie. Presentatie, Vereniging voor Revalidatie bij Slechtziendheid (VRS), Huizen, 9 oktober 2012.
- The effects of compensatory scanning training on mobility in hemianopia patients. Presentatie, Research meeting Clinical and Developmental Neuropsychology, RUG, Groningen, 11 oktober 2012.
- Autorijden met hemianopsie. Presentatie, bijeenkomst Oogheelkundige Fysica, Groningen, 16 november 2012.
- InZicht Hemianopsie. Presentatie en posterpresentatie, Ontmoetingsdag InZicht (ZonMw), Ede, 23 november 2012.
- Rijgedrag, rijvaardigheid en rijgeschiktheid. Presentatie, Symposium Slecht zien en toch autorijden, Congres Nederlands Oogheelkundig Genootschap (NOG), Groningen, 21 maart 2013.
- InZicht Hemianopsie: Effecten van kijkstrategietraining op de mobiliteit bij hemianopsie. Posterpresentatie, InZicht Ontmoetingsdag (ZonMw), Ede, 22 november 2013.
- InZicht Hemianopsie: Onderzoek naar de effecten van kijkstrategietraining op de mobiliteit bij hemianopsie. Presentatie, Trappenberg-lezing 'Behandeling van hemianopsie', Huizen, 29 januari 2014.

- IH-CST: Kijktraining t.b.v. detectie en mobiliteit bij hemianopsiepatiënten. Presentatie, Oostelijk Ooogheelkundig Gezelschap (OOG), Paterswolde, 17 januari 2015.
- Rijgedrag, rijvaardigheid en rijgeschiktheid, Presentatie, Symposium Slecht zien en toch autorijden, Congres Nederlands Oogheelkundig Genootschap (NOG), Groningen, 25 maart 2015.
- Neuropsychologie bij visuele stoornissen. Presentatie, afdeling Neuropsychologie UMCG, Groningen, 19 mei 2015.
- Neuropsychologische diagnostiek bij visuele stoornissen. Presentatie, Research Meeting Clinical and Developmental Neuropsychology, RUG, Groningen, 28 mei 2015.
- Compensatory scanning training and neuropsychological assessment. Presentatie, NextGenVis Workshop, Haren, 26 november 2015.
- Hemianopsie: De effecten van kijktraining op mobiliteit. Presentatie, afdeling Oogheelkunde UMCG, Groningen, 24 februari 2016.

Curriculum vitae

Gera de Haan is geboren op 15 december 1987 te Zwolle. Het eerste jaar van het gymnasium heeft ze gevolgd aan het Agnieten College locatie Carolus Clusius te Zwolle (1999-2000). Deze opleiding heeft ze vervolgd aan het Christelijk Gymnasium Beyers Naudé te Leeuwarden, waar ze in 2005 haar gymnasiumdiploma behaalde (profielen Natuur & Techniek en Natuur & Gezondheid). Aansluitend is ze begonnen met de studie Psychologie aan de Rijksuniversiteit Groningen (RUG), faculteit Gedrags- en Maatschappijwetenschappen. Zowel de bachelortitel (2008) als de mastertitel (2009) behaalde ze cum laude. Voor haar afstudeerscriptie onderzocht ze de invloed van snelheid op het waarnemen van bewegende beelden bij een mevrouw met de zeldzame visuele aandoening akinetopsie. In september 2009 startte ze als promovenda aan de afdeling Klinische en Ontwikkelingsneuropsychologie van de RUG onder leiding van Prof. dr. Wiebo Brouwer, Prof. dr. Oliver Tucha, dr. Joost Heutink en dr. Bart Melis-Dankers. Haar promotieonderzoek, bekend onder de projectnaam *InZicht Hemianopsie*, voerde ze uit in samenwerking met Koninklijke Visio, Bartiméus en het Centraal Bureau Rijvaardigheidsbewijzen (CBR). Ze heeft veel werk verzet in het organiseren van het onderzoek binnen Koninklijke Visio en Bartiméus. De onderzoeksuitkomsten heeft ze op vele nationale en internationale congressen gepresenteerd en daarnaast heeft ze verscheidene onderwijstaken uitgevoerd. Ook volgde ze het BCN PhD Training Program van de onderzoeksschool Behavioural and Cognitive Neuroscience van de Rijksuniversiteit Groningen (afgerond in mei 2014). In 2012 ontving ze de award Highly Recommended Speaker, uitgereikt op het jaarlijkse congres van de Neuropsychological Rehabilitation Special Interest Group in Bergen, Noorwegen. Sinds 2014 werkt ze binnen de Klinische en Ontwikkelingsneuropsychologie van de RUG als onderzoeker aan het project *De invloed van slechtziendheid op neuropsychologische diagnostiek*, een project dat in samenwerking met Koninklijke Visio wordt uitgevoerd. Eind 2016 zal ze als post-doconderzoeker haar onderzoekswerk bij dezelfde afdeling voortzetten. Naast het wetenschappelijk onderzoek heeft ook de klinische praktijk haar grote interesse. Ze is sinds februari 2013 werkzaam als neuropsycholoog bij Koninklijke Visio, met als huidige werklocatie Leeuwarden. Gera ambieert de waardevolle combinatie van wetenschappelijk onderzoek en klinisch werk voort te zetten, zodat de wetenschap en praktijk elkaar kunnen blijven versterken.