The effects of rehabilitative interventions on reading disorders caused by homonymous visual field defects: a meta-analysis focusing on improvement in reading speed

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Abstract

Introduction: Reading disorders caused by homonymous visual field defects (HVFDs) have a significant impact on a patient's quality of life. However, no review has been conducted to evaluate the available evidence on the effects of rehabilitative interventions on reading disorders caused by HVFDs. Thus, the aim of this study was to systematically evaluate the effects of rehabilitative interventions on reading disorders caused by HVFDs.

Methods: We searched the MEDLINE/PubMed, Cochrane Library, ClinicalTrials.gov, CINAHL, and ScienceDirect databases for relevant articles. Relevant search terms were used to identify reports of randomized controlled trials or randomized crossover trials published between January 1990 and December 2021. Only studies that included reading-speed-related outcomes were analyzed. Risk of bias was assessed using the PEDro scale. Meta-analysis was conducted using a random-effects model, and standardized mean differences (SMD) and 95% confidence intervals (CIs) were calculated. Heterogeneity was assessed using the I^2 statistic.

Results: Nine studies were included in the meta-analysis. The results showed that rehabilitative interventions significantly improved reading disorders caused by HVFDs (SMD = 0.30; 95% CI, 0.08-0.51; $P < 0.01$; $I^2 = 0.0\%$). Subgroup analysis showed that reading training significantly improved reading disorders (SMD = 0.35; 95% CI, 0.05-0.66; $P = 0.02$; $I^2 = 0.0\%$).

Conclusion: Reading disorders caused by HVFDs can be improved through rehabilitation. In addition,

reading training for the improvement of eye movement and fixation to compensate for foveal and parafoveal visual field defects may improve reading speed.

Keywords: Homonymous visual field defects; Reading disorder; Rehabilitation; Systematic review; Meta-analysis

Abbreviations: 95% CIs, 95% confidence intervals; FEF, frontal eye field; HVFDs, homonymous visual field defects; PEF, parietal eye field; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO, Prospective Register of Systematic Reviews; RCT, randomized controlled or crossover trial; rtACS, repetitive transorbital alternating current stimulation; SMD, standardized mean differences; tDCS, transcranial direct current stimulation; VRT, visual restoration therapy.

Introduction

Homonymous visual field defects (HVFDs) are characterized by visual field loss caused by post-chiasmatic lesions, such as stroke, brain tumors, and traumatic brain injuries. HVFDs are categorized as hemianopia (loss of vision in half of the left and right visual fields), quadrantanopia (loss of vision in either the upper or lower quadrant of the left and right visual fields), or paracentral scotoma (loss of vision due to dark spots in the paracentral visual fields of both the left and right eyes), depending on the location of brain damage. HVFDs negatively affect activities of daily living, such as searching for objects [1-3] and avoiding obstacles [4,5]. Particularly, patients with reading disorders caused by HVFDs [6-8] show significantly increased rates of progressive or regressive saccades [9] and significantly increased numbers and durations of reading fixations compared to healthy subjects [10]. HVFDs thereby result in decreased speed, misreading, skipping, and guessing while reading. Reduced reading speed leads to reading difficulties in various social situations, such as work and community participation, and makes some activities challenging, such as quickly and accurately reading information on labels when shopping [11], quickly and correctly figuring out numbers when paying bills [11], accurately reading documents, and efficiently typing into a computer [12]. Therefore, it is important to improve reading speed and reading disability caused by HVFDs through rehabilitation to help improve patients' quality of life.

Rehabilitation for HVFDs includes compensatory eye movement training for the eye with the field defect [13-16], visual restoration therapy (VRT), which expands the visual field by stimulating the

neurons that process visual information from the area between the blind and the residual fields [17-20], and training using optic aids [21-23]. Compensatory training includes reading training for the adoption of efficient eye movements [24], visual exploration training to reinforce exploratory ability and response to visual stimuli [15], and multisensory training to improve eye movement by stimulating neurons in the superior colliculus using audio-visual stimulation [13].

The efficacies of the abovementioned rehabilitation interventions have been reported in several studies. However, no review has been conducted to systematically evaluate the available evidence on the effects of rehabilitation interventions on reading disorders. Therefore, the purpose of this study was to conduct a systematic review and meta-analysis with reading speed as the outcome. Reduced reading speed is a major characteristic of reading disorders in patients with HVFDs [6,9]. Reduced reading speed causes a variety of reading-related impairments that disrupt daily life [11] and social participation [12]. Furthermore, we analyzed the effects of individual training modalities, such as reading training and VRT, on reading speed to facilitate the development and improvement of rehabilitation techniques for reading disorders.

Methods

This systematic review and meta-analysis were conducted in accordance with the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The protocol for the review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (https://www.crd.york.ac.uk/prospero/; ID number: CRD42021257589).

Search strategy

The MEDLINE/PubMed, Cochrane Library, ClinicalTrials.gov, CINAHL, and ScienceDirect databases were searched for relevant original articles. The search strategies used for the databases are outlined in Appendices 1a and b. Two search terms were used for the database search: "homonymous visual field defects" and "homonymous hemianopia." These two terms were used to prevent omission of relevant articles.

The inclusion criteria for this systematic review and meta-analysis were as follows: (1) articles published in a peer-reviewed English language journal; (2) articles on randomized controlled trials or randomized crossover trials (RCTs); (3) articles published between January 1990 and December 2021; and (4) articles on studies that included reading-speed-related outcomes. Articles that did not meet these criteria were excluded. Evaluation of reading speed-related outcomes in a study was included as a criterion because reduced reading speed is a major characteristic of reading disorders caused by HVFDs [6,9], and causes various reading-related impairments, such as reading errors and guessing [7]. The duration of the interventions was not specified because this is the first study in which the effects of

rehabilitative interventions on reading disorders caused by HVFDs were systematically analyzed.

Article selection

In the first screening, we read the titles and abstracts of extracted articles and excluded those that did not meet the inclusion criteria. Articles duplicated across databases were excluded as well. If the title and abstract of an article clearly indicated that the study was an RCT but did not clearly describe the outcomes of the study, we included the article in the secondary screening. Thereafter, we created a dataset of the articles included for secondary screening and extracted their full texts.

In the secondary screening, we read the full texts of the articles selected in the first screening. The selected articles that met the eligibility criteria were included in the systematic review and meta-analysis.

Three reviewers (TM, SS and HO) independently selected the articles. The three reviewers selected all the articles in the same way to avoid potential bias and omission of articles from the search. Any discrepancy was resolved through discussions among the reviewers.

Assessment of the risk of bias

The PEDro scale [25] was used to assess the risks of bias in the analyzed studies. The PEDro scale has ten items for evaluating the level of evidence obtained from an RCT and includes domains such as allocation concealment and blinding. Total scores of 9-10, 8-6, 5-4, and ≤3 points are considered

"excellent," "good," "moderate," and "poor," respectively [26]. TM and SS independently assessed the risks of bias in the analyzed studies. Any discrepancy was resolved through discussions among the reviewers.

Data synthesis

Participant characteristics (sample size, sex, age, duration since the onset of the HVFDs, etiology, type of visual field defect, and the affected side of the visual field) and study characteristics (country, type and duration of intervention, assessment tools used, and results of between- and within-group comparisons of pre- and post-interventions) were independently extracted from the articles included in the secondary screening by three reviewers (TM, HO, and SS). Any discrepancy was resolved through discussions among the reviewers.

Meta-analysis

The meta-analysis was conducted by extracting and analyzing the means and standard deviations of the reading speed-related outcomes reported in the articles included in the secondary screening. We considered reading speed to be the outcome that could most directly and accurately reflect reading disorders. It should be noted that reading disorders caused by HVFDs result from a reduction in visual span while reading [10, 27]; thus, reduced visual span is a central feature of reading disorders. In addition to reduced visual span, reading disorders could be caused by slower and more inaccurate eye movements.

However, direct and accurate assessment of visual span in eyes with HVFDs is difficult because eyes with HVFDs exhibit fixation instability [28]. In addition, eye movements do not necessarily reflect reading abilities. On the other hand, reading speed is not only related to visual span [29, 30] but can also indicate the speed/accuracy of eye movements related to reading. Therefore, in this study, reading speed was determined to be the most valid outcome for assessing reading disorders.

The data integration method used in this study was a random-effects model because the assessment tools and languages used in the included studies may vary. The effect sizes were determined using standardized mean differences (SMD) and 95% confidence intervals (95% CIs) and are presented using forest plots. SMDs are described as Cohen's d. The DerSimonian-Laird method was used for analysis. For analysis of studies with outcomes that followed a normal distribution and were presented as medians and interquartile ranges, we used the methods described Luo et al. [31] and Wan et al. [32] (https://www.math.hkbu.edu.hk/~tongt/papers/median2mean.html) to convert the medians and interquartile ranges into means and standard deviations, respectively. Regarding the handling of means and standard deviations for randomized crossover trials, we only considered outcomes in the first period to eliminate potential interactions that could occur in the second period [33-35].

For RCTs with two or more interventions or control groups, the groups were combined into one for analysis based on the method described in a previous study [36]. The formulae used for calculating the sample size (N), mean (M), and standard deviation (SD) for the combined groups are as follows: for

Group 1, the sample size was N_1, the mean was M_1, and the standard deviation was SD_1; for Group 2, the sample size was N_2, the mean was M_2, and the standard deviation was SD_2.

$$N = N_1 + N_2 \tag{1}$$

$$M = \frac{N_1 M_1 + N_2 M_2}{N_1 + N_2} \tag{2}$$

$$SD = \sqrt{\frac{(N_1 - 1){SD_1}^2 + \left({N_2}^2 - 1\right){SD_2}^2 + \frac{N_1 N_2}{N_1 + N_2}\left({M_1}^2 + {M_2}^2 - 2M_1 M_2\right)}{N_1 + N_2 - 1}} \tag{3}$$

Heterogeneity was assessed using the I^2 statistic. For 95% CIs, 0-25%, 25-50%, 50-75%, and >75% were considered to indicate low, moderate, strong, and very strong heterogeneity, respectively [37]. Publication bias was assessed using funnel plots. For articles that did not include data on means and standard deviations, the authors were contacted via email, and we requested for data on the missing numerical values. If the authors did not have the data or did not reply to the email, the article was excluded from the meta-analysis. Statistical significance was set at $P < 0.05$, with a confidence interval of 95%. All statistical analyses were performed using EZR version 1.40 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [38].

Results

Results of the systematic database search

Fifteen articles were included in the systematic review and nine articles were included in the meta-analysis. Of the articles that did not meet the eligibility criteria, eight were not reports of RCTs, nine did not meet any of the four criteria, and one was a conference abstract. The inclusion process is illustrated in Figure 1.

Insert Figure 1

Participant characteristics

A total of 613 participants were enrolled in the 15 studies included in the systematic review. The mean age of the participants ranged from 49.7 years [39] to 68.6 years [40]. The mean duration from the onset of HVFDs ranged from 4.2 weeks [41] to 276 months [42]. Etiologies were reported in 13 articles and included ischemic stroke, cerebral hemorrhage, brain tumor, and traumatic brain injury. Visual field defects were reported in 14 articles and included left visual field defects (299 participants) and right

visual field defects (273 participants). The characteristics of the participants are shown in Table 1.

Insert Table 1

Study characteristics

Compensatory training was performed in ten studies (reading training, six studies; visual exploration training, three studies; and multisensory training, one study). VRT was performed in four studies, and training using optic aids was performed in one study. Two types of RCTs were identified in the database search: "parallel randomized controlled trials" and "randomized crossover trials". The RCTs identified in the search are outlined in Table 2 according to their types.

Insert Table 2

Results of interventions

Compensatory training: reading training

Aimola et al. [42], Schuett et al. [43], Schuett et al. [44], and Zihl et al. [45] used a time-limited reading training method, which involved reading target strings. Significant post-training improvements were reported in the abovementioned studies.

Spitzyna et al. [39] used a training method that involved reading texts that scrolled horizontally from right to left on the screen and observed significant improvements post-training.

Kuester-Gruber et al. [46] trained participants to read vertical text; however, there were no significant differences between the pre-and post- training reading speeds of the participants.

Compensatory training: visual exploration training

Crotty et al. [40], de Haan et al. [47], and Roth et al. [48] trained participants to search for objects using eye movements. However, no significant improvement was observed in any of the studies.

Compensatory training: multisensory training

Keller and Lefin-Rank [41] trained their intervention group using audio-visual stimulation of the blind or residual visual field and reported significant improvements post-intervention.

Visual restoration therapy

Elshout et al. [49] and Mödden et al. [50] stimulated the area between the residual and blind visual fields using high-contrast and colored stimuli, respectively. Elshout et al. [49] reported significant improvement after the intervention, whereas Mödden et al. [50] did not.

Plow et al. [51] administered VRT by combining visual stimulation with transcranial direct current stimulation (tDCS). However, they observed no improvement after within- and between-group comparisons.

Räty et al. [52] administered VRT using repetitive transorbital alternating current stimulation (rtACS) and tDCS. The results of their study showed that participants who underwent either rtACS or tDCS did not show significant improvement, whereas those that underwent both rtACS and tDCS showed significant improvement.

Optical aids

Optical aids were used in only one study [53]. Prisms were used for the intervention; however, the optical aid did not significantly improve reading speed compared to visual search training or usual occupational therapy.

Assessment of risk of bias

The mean PEDro scale score was 5.60±1.54. The internal validity of the scale was moderate.

Regarding blinding, therapists were blinded to the details of participant grouping in five studies, participants were blinded to their grouping details in six studies, and allocation concealment was performed in four studies. The scores of the studies are presented in Table 3.

Insert Table 3

Meta-analysis

Of the 15 articles extracted from the systematic review, six were excluded from the meta-analysis because information on the study outcomes could not be obtained from the authors via email. Therefore, a total of nine articles were included (five on reading training, two on visual exploration training, and two on VRT). None of the included articles was missing data on the outcomes of the study.

The results of the studies are shown in Figure 2a. The results of the meta-analyses for reading training, visual exploration training, and VRT are shown in Figures 2b, 2c, and 2d, respectively. The funnel plots are shown in Figures 3a, 3b, 3c, and 3d, respectively.

Insert Figure 2 a-d

Insert Figure 3 a-d

Regarding studies on VRT, Räty et al. [52] included three separate RCTs in one study; thus, RCTs were analyzed as separate studies. Therefore, 11 studies were included in the creation of the forest and funnel plots for all studies, whereas four studies were included in the creation of the forest and funnel plots for VRT.

The results of the meta-analysis showed that rehabilitation for reading disorders significantly improved reading speed (SMD = 0.30; 95% CI, 0.08-0.51; $P < 0.01$; $I^2 = 0.0\%$). Furthermore, subgroup analyses showed that reading training significantly improved reading speed (SMD = 0.35; 95% CI, 0.05-0.66; $P = 0.02$; $I^2 = 0.0\%$). However, no significant differences in reading speed were observed after visual exploration training (SMD = 0.32; 95% CI, -0.17-0.81; $P = 0.20$; $I^2 = 0.0\%$) and VRT (SMD = 0.20; 95% CI, -0.18-0.59; $P = 0.88$; $I^2 = 0.0\%$).

Regarding publication bias, the funnel plots were almost equally distributed on the left and right sides, except for the funnel plot for VRT.

Discussion

In this systematic review and meta-analysis, we analyzed the effectiveness of rehabilitation for reading disorders caused by HVFDs. The results showed that rehabilitation for reading disorders significantly improved reading speed. In addition, subgroup analyses showed that reading training that involves using eye movements to read words and letters was effective in improving reading disorders caused by HVFDs. However, visual exploration training and VRT did not significantly improve the reading disorders.

Mechanism underlying the improvement of reading speed using reading training

Reading training is a learning method that trains the subject to perform eye movements and control saccades and fixations more efficiently, thereby compensating for visual field loss. This intervention method has the potential to effectively improve reading speed.

In the four studies on reading training analyzed in the present systematic review, including the study by Aimola et al. [42], patients had to read text strings within a time limit. This forced them to shift their visual attention faster and more accurately and adjust their saccade length and fixation position. In the study by Spitzyna et al. [41], patients began reading texts presented at a slow scrolling speed, and once they were comfortable with that speed, they moved to texts presented at a faster speed, thereby inducing optokinetic nystagmus (OKN), which indirectly improves conscious eye movement. Although

the two intervention methods described above are different, they both promote efficient eye movement and compensate for deficits in the visual field. It is possible that these interventions strengthened the functional connectivity of the frontal eye field (FEF), parietal eye field (PEF), and supplementary eye field, which are the basis of saccades and fixations [54], and may have compensated for visual field defects caused by damage to the occipital lobe and optic tract. Reading training may strengthen these FEF and PEF networks, resulting in more efficient control of saccades and fixations, which improves reading speed.

The results of the present study indicated that visual exploration training, which involves the use of eye movements to compensate for visual field defects, did not significantly improve reading speed. This is probably due to the difference between the types of eye movements used to compensate for visual field defects while reading and those used in visual exploration training. In visual exploration training, dynamic stimuli are used to induce gaze shifts [40, 47, 48]. This forces the subject to learn compensatory gaze shifts, including oblique, up, and down shifts, in addition to the horizontal gaze shifts necessary for reading, across the entire blind visual field [55-57]. On the other hand, reading training compensates for the "perceptual window," [58] which consists of the foveal and parafoveal regions, by making the subject learn the horizontal gaze shifts necessary for reading. Therefore, visual exploration training may not significantly improve reading disorders caused by HVFDs because it does not sufficiently improve the horizontal saccades necessary to improve reading speed.

The possibility of improving reading speed by using VRT

The results of the meta-analysis conducted in this study indicated that VRT does not significantly improve reading speed. However, some studies have shown that VRT significantly improves reading speed. VRT involves continuous provision of high-contrast stimulation to the area between the resdidual and blind visual fields [49], and administration of rtACS and tDCS [52].

In the study by Elshout et al. [49], participants were continuously provided with high-contrast stimuli based on the hypothesis that visual field expansion is correlated with improved reading speed [6]. However, Räty et al. [52] reported that although VRT resulted in significant visual field expansion, it failed to improve reading speed. The reason for the observation of a significant improvement in the study by Elshout et al. [49] but not in that by Räty et al. [52], despite the fact that the same high-intensity stimuli were used in both studies, is that Elshout et al. [49] reported a parafoveal visual field expansion equivalent to 1–5° in visual angle, whereas Räty et al. reported significant visual field expansion [52] but did not indicate the extent of the expansion. Perhaps it is important to improve the foveal and parafoveal visual fields when aiming to expand the visual field and improve reading speed using VRT.

Improvement in saccades and fixations using VRT could be important for improving reading speed. In the study by Räty et al. [52], the combination of rtACS and tDCS significantly improved reading speed. The combination of rtACS and tDCS improves the network of brain functions responsible for more

effective saccades and fixations [52]. Although rtACS attempts to improve saccades and fixation and expand the visual field, its effect is not sufficient. Combining rtACS with tDCS, which improves the frontal and occipital networks, is important for effective and sufficient utilization of saccades and fixation to improve reading speed. In the study by Räty et al. [52], rehabilitation using rtACS or tDCS alone did not significantly improve reading speed. Therefore, sufficient recovery of saccades and fixations, which are necessary for reading, may be important for improving reading speed using VRT.

Limitations

This study has several limitations. First, the number of studies included in the systematic review and meta-analysis was small (15 and 9, respectively), as were their sample sizes (613 and 341, respectively). Therefore, more RCTs on reading training for reading disorders caused by HVFDs are needed. Second, the languages of all the countries in which the analyzed studies were conducted are read horizontally and from left to right. Thus, whether the reading training performed in these studies will produce similar results with Asian languages that are adapted to both horizontal and vertical reading or languages that are read from right to left is unclear. Therefore, further testing is needed to determine whether these rehabilitation techniques, which were effective in the studies analyzed in this systematic review and meta-analysis, can be applied to languages with the abovementioned features. Furthermore, although the present meta-analysis showed the effectiveness of rehabilitation for reading disorders, the

results indicated that the SMDs for improvement in reading speed after rehabilitation and reading training were 0.3 and 0.35, respectively, both of which indicate small effect sizes [59]. A possible reason for this is that the duration of the interventions was not controlled. These results suggest that the current rehabilitation approaches to the improvement of reading disorders and reading speed may not yield sufficient effect sizes. Further research is needed to develop new and advanced approaches for improving reading disorders and the quality of life of patients with HVFDs.

Conclusion

The results of this systematic review and meta-analysis showed that reading disorders caused by HVFDs can be improved through rehabilitation. In particular, the results indicated that reading training is effective in improving reading disorders. To improve reading speed using VRT, it is important to focus on expanding the foveal and parafoveal areas rather than the visual field. Furthermore, in addition to expanding the visual field, it is necessary to provide effective interventions for improving saccades and fixation, which are necessary for reading.

Conflict of Interest Statement

The authors declare no conflicts of interest relevant to this study.

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Table 1. Characteristics of participants of studies: compensatory training (reading training) 1/2

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Aimola et al. (2014) [42] †	Intervention group: 28	Total: 36/16	Intervention group: 61.43 (mean)	Range: 3 - 276 months	Ischemic stroke: 39 Hemorrhage: 6 Traumatic Brain Injury: 6 Tumor: 1	Type: Hemianopia; 40, Quadrantanopia; 12 Side: Left; 26, Right; 26
	Control group: 24		Control group: 63.96 (mean)			
Kuester- Gruber et al. (2020) [46] †	Intervention group: 11	Both groups: Not reported	Both groups: Not reported	Both groups: Not reported	Both groups: Not reported	Type: Hemianopia; 20; Quadrantanopia: 1 Side: Left; 11, Right; 10
	Control group: 10					
Schuett et al. (2008) [43] †	Intervention group: 20	Intervention group: 3/17	Intervention group: 58.7 (mean)	Intervention group: 31.0 weeks (mean)	Ischemic stroke: 33 Hemorrhage: 7	Type: Hemianopia; 24, Quadrantanopia; 8, Paracentral scotoma; 8 Side: Left; 16, Right: 24
	Control group: 20	Control group: 3/17	Control group: 58.8 (mean)	Control group: 28.9 weeks (mean)		
Schuett et al. (2012) [44] †	Group A (control block → intervention block): 18	Group A: 15/3	Group A: 64.0 (mean)	Group A: 26.6 weeks (mean)	Ischemic stroke: 34 Tumor operation: 2	Type: Hemianopia; 25, Quadrantanopia; 5, Paracentral scotoma; 6 Side: Left; 16, Right; 20
	Group B (intervention block → control block): 18	Group B: 15/3	Group B: 63.7 (mean)	Group B: 20.1 weeks (mean)		

Table 1. Characteristics of participants of studies: compensatory training (reading training) 2/2

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Spitzyna et al. (2007) [39] †	Group 1 (intervention block only): 11	Group 1: 6/5	Group 1: 49.7 (mean)	Group 1: 7.3 months (mean)	Ischemic stroke: 11 Hemorrhage: 2 Head injury: 2 Tumor: 2 Others: 2	Type: Hemianopia; 14, Quadrantanopia; 5 Side: Right; 19
	Group 2 (control block → intervention block): 8	Group 2: 7/1	Group 2: 64.4 (mean)	Group 2: 1.3 months (mean)		
Zihl et al. (2021) [45]	Group 1 (visual exploration → reading): 33	Group 1: 25/8	Group 1: 59.8 (mean)	Group 1: 24.8 weeks (mean)	Group 1: Cerebrovascular disease; 30, Tumor, operated; 3	Type: Hemianopia; 33 Side: Left; 19, Right; 14
	Group 2(reading → visual exploration): 31	Group 2: 21/10	Group 2: 59.9 (mean)	Group 2: 23.3 weeks (mean)	Group 2: Cerebrovascular disease; 27, Closed head trauma; 3, Tumor, operated; 1	Type: Hemianopia: 31 Side: Left; 16, Right; 15
	Group 3 (no training → visual exploration → reading): 33	Group 3: 23/10	Group 3: 57.1 (mean)	Group 3: 27.4 weeks (mean)	Group 3: Cerebrovascular disease; 26, Closed head trauma; 2, Tumor, operated; 5	Type: Hemianopia: 33 Side: Left; 17, Right; 16

Table 1. Characteristics of participants of studies: compensatory training (visual exploration training)

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Crotty et al. (2018) [40] †	Intervention group: 13	Total: 13/11	Intervention group: 68.6 (mean)	Intervention group: 42.4 days (mean)	Not reported	Type: Hemianopia: 24 Side: Left: 11, Right: 12, Bilateral: 1
	Control group: 11		Control group: 60.7 (mean)	Control group: 46.9 days (mean)		
de Haan et al. (2015) [47] †	Intervention group: 26	Intervention group: 18/8	Intervention group: 55 (mean)	Intervention group: 18 months (mean)	Ischemic stroke: 36 Hemorrhage: 5 Traumatic Brain Injury: 3 Others: 5	Type: Hemianopia; 39. Quadrantanopia; 10 Side: Left; 33, Right; 16
	Control group: 23	Control group: 14/9	Control group: 57 (mean)	Control group: 22 months (mean)		
Roth et al. (2009) [48]	Intervention group: 15	Intervention group: 11/4	Intervention group: 60.467 (mean)	Intervention group: 39.200 months (mean)	Ischemic stroke: 17 Hemorrhage: 4 Stroke (not specified): 5 Others: 4	Type: Hemianopia; 24, Quadrantanopia; 6 Side: Left; 15, Right; 15
	Control group: 15	Control group: 8/7	Control group: 60.267 (mean)	Control group: 87.867 months (mean)		

Table 1. Characteristics of participants of studies: compensatory training (multisensory training)

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Keller and Lefin-Rank. (2010) [41]	Intervention group: 10	Intervention group: 6/4	Intervention group: 54.7 (mean)	Intervention group: 8.5 weeks (mean)	Stroke: 18 Tumor: 1 Traumatic Brain Injury: 1	Type: Hemianopia; 13, Quadrantanopia; 7 Side: Left; 12, Right; 8
	Control group: 10	Control group: 6/4	Control group: 63.6 (mean)	Control group: 4.2 weeks (mean)		

Table 1. Characteristics of participants of studies: VRT 1/2

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Elshout et al. (2016) [49] †	Point group: 13 Intact (control) → Defect (intervention); 6 Defect → Intact; 7	Total: 22/5	Total: 51.2 (mean) Range: 29 - 74	26.3 months (mean)	Ischemic stroke: 22 Hemorrhage: 5	Type: Hemianopia: 21, Quadrantanopia; 3, Scotoma: 3
	Flow group: 14 Intact → Defect; 7 Defect → Intact; 7					
Mödden et al. (2012) [50]	VRT group: 15	VRT group: 10/5	VRT group: 58.3 (mean)	VRT group: 4.9 weeks (mean)	All three groups: Not reported	Type: Hemianopia; 10, Quadrantanopia; 5 Side: Left; 8, Right; 7
	Compensatory training group: 15	Compensatory training group: 9/6	Compensatory training group: 57.1 (mean)	Compensatory training group: 4.9 weeks (mean)		Type: Hemianopia; 12, Quadrantanopia; 3 Side: Left; 10, Right; 5
	Occupational therapy group: 15	Occupational therapy group: 7/8	Occupational therapy group: 59.0 (mean)	Occupational therapy group: 4.3 weeks (mean)		Type: Hemianopia; 10, Quadrantanopia; 5 Side: Left; 10, Right; 5
Plow et al. (2012) [51]	Total: 12	Total: 5/7	Total: 59.38 (mean)	Total: 39.83 months (mean)	Stroke: 10 Surgical trauma: 2	Type: Hemianopia; 7, Quadrantanopia; 5 Side: Not reported

Table 1. Characteristics of participants of studies: VRT 2/2

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Räty et al. (2021) [52] †	Experiment 1 tDCS/rtACS: 8 rtACS: 8 Sham: 8	Experiment 1 tDCS/rtACS: 8/0 rtACS: 7/1 Sham: 6/2	Experiment 1 (median) tDCS/rtACS: 52 rtACS: 54 Sham: 64	All groups: lesion age > 6 months	All groups: ischemic or hemorrhagic stroke	Type: Hemianopia; 24 Side: Experiment 1 tDCS/rtACS: Left; 3, Right; 5 rtACS: Left; 4, Right; 4 Sham: Left; 3, Right; 5
	Experiment 2 rtACS: 9 Sham: 9	Experiment 2 rtACS: 6/3 Sham: 7/2	Experiment 2 (median) rtACS: 59 Sham: 57			Type: Hemianopia; 18 Side: Experiment 2 rtACS: Left; 2, Right; 7 Sham: Left; 3, Right; 6
	Experiment 3 tDCS: 7 Sham: 7	Experiment 3 tDCS: 4/3 Sham: 6/1	Experiment 3 (median) tDCS: 72 Sham: 65			Type: Hemianopia; 14 Side: Experiment 3 tDCS: Left; 2, Right; 5 Sham: Left; 0, Right; 7

Table 1. Characteristics of participants of studies: optic aids

Study (year)	Sample Size	Sex (Male/Female)	Age (year)	Duration Since the Onset of the HVFDs	Etiology	Type and Side of Visual Field Defect (n)
Rowe et al. (2017) [53]	Optical aid group: 26	Prism group: 22/4	Prism group: 69.9 (mean)	Prism group: 75.5 days (mean)	Prism group: Ischemic stroke; 25 Hemorrhagic stroke; 1	Type: Hemianopia; 26 Side: Left; 17, Right; 9
	Visual search training group: 30	Visual search training group: 17/13	Visual search training group: 70.9 (mean)	Visual search training group: 73.8 days (mean)	Visual search training group: Ischemic stroke; 28 Hemorrhagic stroke; 2	Type: Hemianopia; 30 Side: Left; 13, Right; 17
	Control group: 29	Control group: 20/9	Control group: 66.2 (mean)	Control group: 81.2 days (mean)	Control group: Ischemic stroke; 28 Hemorrhagic stroke; 1	Type: Hemianopia; 29 Side: Left; 18, Right; 11

NOTE: † indicates that the article is included in the meta-analysis.

Table 2. Study characteristics of studies: compensatory training (reading training) 1/3

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Aimola et al. (2014) [42]†	United Kingdom	Parallel	Intervention group: reading training	1 hour of training per day for approximately 5 weeks	Four modified passages consisting of 200 words taken from 'The Grey Gentlemen' (Ende, 1974)	Reading speed (wpm)	$P < .01$*	Entire group: $P = .001$* Both sides of visual field defect: significant change
			Control group: visual attention training					Entire group: NS Both sides of visual field defect: NS
Kuester-Gruber et al. (2020) [46]†	Germany	Crossover	Intervention group: reading training (vertical reading)	Both groups: 30 minutes, twice a day, on 5 days a week, for 4 weeks	International Reading Speed Texts, IReST, German version	Reading speed (wpm)	Not reported	Intervention group: NS
			Control group: reading training (horizontal reading)					Control group: $p = 0.004$*

Table 2. Study characteristics of studies: compensatory training (reading training) 2/3

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Schuett et al. (2008) [43] †	Germany	Parallel	Intervention group: reading training (Arabic-digit reading)	Intervention group: 9.6 ± 2.0 weeks, 1 session lasted up to 45 minutes, average 10 sessions.	A standardized reading test consisted of 200 words (in 14pt Arial font) taken from Gotthold E. Lessing's animal fables (in German)	Reading speed (wpm)	NS	$P < 0.001$ *
			Control group: reading training (text reading)	Control group: 10.5 ± 2.0 weeks, 1 session lasted up to 45 minutes, average 11 sessions.				$P < 0.001$ *
Schuett et al. (2012) [44] †	Germany	Crossover	Intervention block: reading training	Group A: 11.6 ± 4.1 sessions; Group B: 12.6 ± 2.4 sessions All sessions: 1 session lasted up to 45 minutes.	A standardized reading test consisted of 200 words (in 14pt Arial font) taken from Gotthold E. Lessing's animal fables (in German)	Reading speed (wpm)	$P < 0.001$ *	Group A: $P < 0.001$ * Group B: $P < 0.001$ *
			Control block: visual exploration training	Group A: 12.3 ± 3.4 sessions; Group B: 11.5 ± 2.4 sessions All sessions: 1 session lasted up to 45 minutes.			$P = 0.035$ *	

Table 2. Study characteristics of studies: compensatory training (reading training) 3/3

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Spitzyna et al. (2007) [39]†	United Kingdom	Crossover	Intervention block: reading training (reading horizontally scrolling text)	400 minutes of rehabilitation (20 sessions × 20 minutes) over approximately 4 weeks	Neale analysis of reading	Reading speed (wpm)	$p < 0.001$*	Group 1: $p < 0.001$* Group 2: $p < 0.007$*
			Control block: visual exploration training				NS	Group2: NS
Zihl et al. (2021) [45]	Germany	Crossover	Intervention block: reading training	Intervention block: Group 1; 11.2 sessions Group 2; 11.5 sessions Group 3; 12.3 sessions	A standardized reading test consisted of 200 words (in 14pt Arial font) taken from Gotthold E. Lessing's animal fables (in German)	Reading speed (wpm)	Improvements after training were practice-dependent and task-specific but detailed values of wpm could not obtain.	
			Control block 1: visual exploration training	Control block 1: Group 1; 11.2 sessions Group 2; 10.7 sessions Group 3; 12.1 sessions				
			Control block 2: Not trained	None				

Table 2. Study characteristics of studies: compensatory training (visual exploration training) 1/3

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Crotty et al. (2018) [40] †	Australia	Parallel	Intervention group: visual exploration training (static and mobility scanning device)	Intervention group: The static scanning device; 3 weeks The mobility scanning device; 4 weeks	Reading speed for the Pepper Visual Skills for Reading test (VSRT)	Reading speed (wpm)	NS	Not reported
			Control group: occupational therapy and mobility instruction promoting visual scanning and mobility training	Control group: Determined by the training therapist				

Table 2. Study characteristics of studies: compensatory training (visual exploration training) 2/3

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
de Haan et al. (2015) [47]†	Netherland	Parallel	Intervention group: visual exploration training (scanning and mobility training)	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 Radner reading chart Text reading test consisted of approximately 400 words	Reading speed (wpm)	NS	Wpm for the Radner Reading Chart (n = 24): NS Wpm for the text reading test (n = 24): NS
			Control group: Not trained					Wpm for Radner Reading Chart (n = 21): NS Wpm for the text reading (n = 21): NS

Table 2. Study characteristics of studies: compensatory training (visual exploration training) 3/3

Roth et al. (2009) [48]	**Germany**	**Parallel**	**Intervention group: visual exploration training (explorative saccade training)**	**Two 30 minutes sessions per day, 5 days a week, for 6 weeks**	**International Reading Speed Test, IReST**	**Reading speed (wpm)**	**NS**	**NS**
			Control group: VRT (flicker training)					

Table 2. Study characteristics of studies: compensatory training (multisensory training)

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Keller and Lefin-Rank. (2010) [41]	Germany	Parallel	Intervention group: multisensory training (audio-visual exploration training)	Both groups: each session lasting 30 minutes over 3 weeks	2 standardized reading tests consisted of 180 words each	Reading speed (seconds)	$P = 0.03^{*}$	Intervention group: $P < .01^{*}$
			Control group: visual exploration training					Control group: NS

Table 2. Study characteristics of studies: VRT 1/2

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Elshout et al. (2016) [49]†	Netherland	Crossover	Intervention block: VRT (defect side training)	Both groups: 1 h a day, 5 days a week during 8 weeks	Two different texts (15-point Arial font; between 88 and 165 words)	The percentage increase in wpm	Not reported	Defect: p = 0.002*
			Control group: VRT (low-contrast training of the intact visual field)					Intact: p=0.011*
Mödden et al. (2012) [50]	Germany	Parallel	Intervention group 1: VRT (stimuli toward visual field border)	Intervention group 1 and control group 1: 30 minutes, and a total of 15 sessions	The standardized texts of the Wechsler Memory Test	Reading speed (wpm)	NS	Not reported
			Control group 1: visual exploration training					
			Control group 2: occupational therapy (using stimulation of daily activity tasks)	Control group 2: 30-minute sessions, and a total of 15 sessions				

Table 2. Study characteristics of studies: VRT 2/2

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Plow et al. (2012) [51]	The United States	Parallel	Intervention group: VRT and tDCS Control group: VRT and sham tDCS	Both groups: two half-hour sessions, three times a week for three months	The Minnesota Reading (MNREAD) standardized test	Reading speed at three print sizes (large, medium, and small): wpm	All print sizes: NS	All print sizes: NS
Räty et al. (2021) [52] †	Experiment 1: Germany	Parallel	Intervention group: rtACS/tDCS Control group 1: rtACS/sham tDCS Control group 2: sham rtACS/sham tDCS	20–40 minutes daily stimulation within a 2-week period	International reading speed test (IResT), validated for German (Experiment 1), Finnish (Experiment 2), and Italian (Experiment 3) languages	Reading speed (wpm)	NS	Only rtACS/DCS group showed significant difference (p = 0.005*)
	Experiment 2: Finland		Intervention group: rtACS Control group: sham rtACS				NS	NS
	Experiment 3: Italy		Intervention group: tDCS Control group: sham tDCS				NS	NS

Table 2. Study characteristics of studies: optical aids

Study	Country	Study design	Type of Intervention	Intervention Duration	Assessment Tools	Outcome Measure	Results	
							Between-groups	Within-group
Rowe et al. (2017) [53]	United Kingdom	Parallel	Optical aid group: using prism	Optical aid group: a minimum of 2 hours daily, for a minimum 6 weeks	The Radner reading test	Reading speed (seconds)	NS	NS
			Visual search training group: visual exploration training	Visual search training group: 30 minutes daily for a minimum 6 weeks				
			Control group: Not trained	Control group: None				

NOTE: * indicates that the results show significant effect.; † indicates that the article is included in the meta-analysis.; NS: non-significant.; "Parallel" means that this study is a parallel randomized trial.; "Crossover" means that this study is a randomized crossover trial.

Table 3. The risk of bias for included studies

Study	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	Total
Aimola et al (2014)	○	○	×	○	×	×	×	×	×	○	○	4
Crotty et al (2018)	○	○	○	○	○	×	×	○	○	○	○	8
de Haan et al (2015)	○	○	×	○	○	×	×	○	×	○	○	6
Elshout et al. (2016)	○	○	○	○	○	×	×	○	×	×	○	6
Keller and Lefin-Rank (2010)	○	○	×	○	×	×	×	○	×	○	○	5
Kuester-Gruber et al (2021)	○	○	×	×	×	×	×	○	×	×	○	3
Mödden et al (2012)	○	○	×	×	○	○	×	○	×	○	○	6
Plow et al (2012)	○	○	×	×	○	○	×	○	○	○	○	7
Räty et al (2021)	○	○	○	○	○	○	×	○	○	○	○	9
Roth et al (2009)	○	○	×	○	×	○	×	○	×	○	○	6
Rowe et al (2017)	○	○	○	○	×	×	○	×	×	×	×	4
Schuett et al (2008)	○	×	×	○	×	×	×	○	○	○	○	5
Shuett et al (2012)	○	○	×	○	×	×	×	○	○	○	○	6
Spitzyna et al (2007)	○	×	×	○	×	○	×	×	×	○	○	4
Zihl et al (2021)	○	○	×	○	×	×	×	○	○	×	○	5

NOTE: ○ means that the article fulfills the item.; × means that the article does not fulfill the item.; "Total" means the sum of ○ for #2 to #11.

#1: Eligibility criteria were specified (no points awarded)

#2: Subjects were randomly allocated to groups

#3: Allocation was concealed

#4: The groups were similar at baseline regarding the most important prognostic indicators

#5: There was blinding of all subjects

#6: There was blinding of all therapists who administered the therapy

#7: There was blinding of all assessors who measured at least one key outcome

#8: Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups

#9: All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by “intention to treat”

#10: The result of between-group comparisons were reported for at least one key outcome

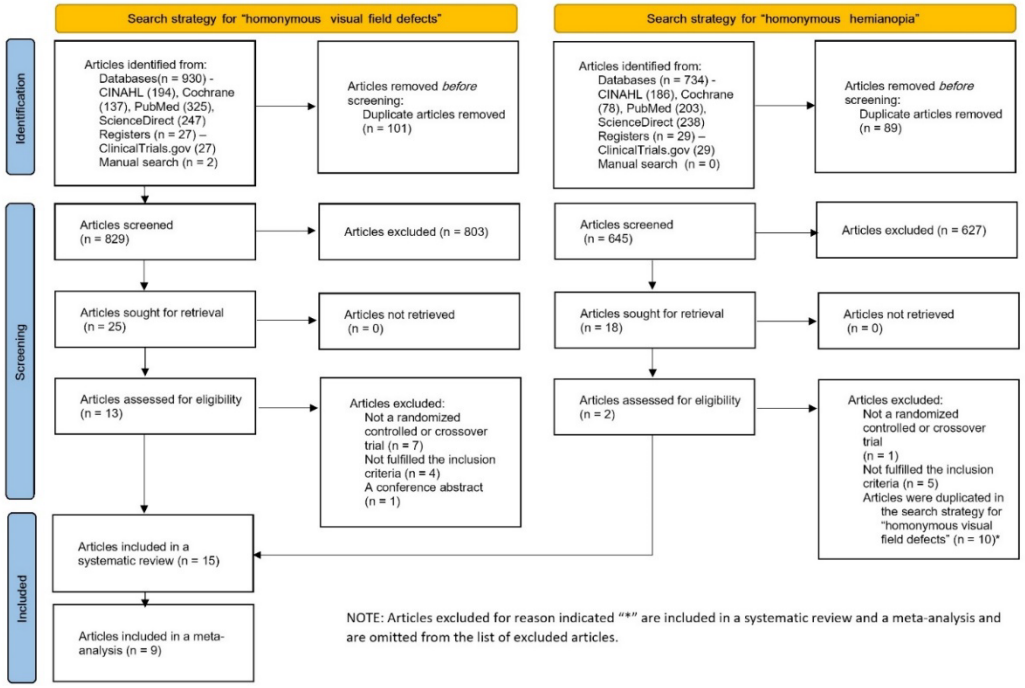
#11: The study provides both point measures and measures of variability for at least one key outcome

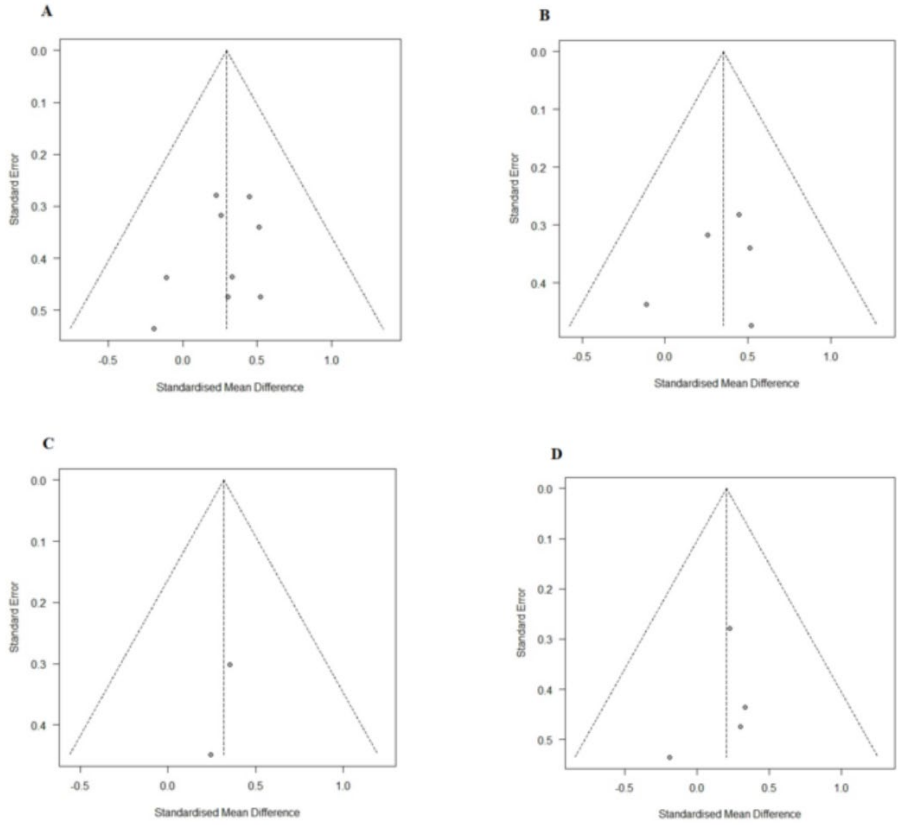
Figure Legends

Fig. 1 Flow diagram for the article selection.

Fig. 3 Funnel plots for the meta-analysis. Figure 3 a. Funnel plot for all rehabilitative interventions. Figure 3 b. Funnel plot for reading trainings. Figure 3 c. Funnel plot for visual exploration trainings. Figure. 3 d. Funnel plot for visual restoration therapies.

Fig. 2 Forest plots for meta-analysis. **Due to the large size of the figures, these figures are included in the Supplementary information.** Figure 2 a. Forest plot showing the degree of improvement in reading speed through all rehabilitative interventions. Figure 2 b. Forest plot showing the degree of improvement in reading speed through reading trainings. Figure 2 c. Forest plot showing the degree of improvement in reading speed through visual exploration trainings. Figure 2 d. Forest plot showing the degree of improvement in reading speed through visual restoration therapies.


Search strategy for "homonymous visual field defects"
Search strategy for "homonymous hemianopia"
Identification
Screening
Included
Articles identified from: Databases(n = 930) - CINAHL (194), Cochrane (137), PubMed (325), ScienceDirect (247) Registers (n = 27) – ClinicalTrials.gov (27) Manual search (n = 2)
Articles removed before screening: Duplicate articles removed (n = 101)
Articles identified from: Databases (n = 734) - CINAHL (186), Cochrane (78), PubMed (203), ScienceDirect (238) Registers (n = 29) – ClinicalTrials.gov (29) Manual search (n = 0)
Articles removed before screening: Duplicate articles removed (n = 89)
Articles screened (n = 829)
Articles excluded (n = 803)
Articles screened (n = 645)
Articles excluded (n = 627)
Articles sought for retrieval (n = 25)
Articles not retrieved (n = 0)
Articles sought for retrieval (n = 18)
Articles not retrieved (n = 0)
Articles assessed for eligibility (n = 13)
Articles excluded: Not a randomized controlled or crossover trial (n = 7) Not fulfilled the inclusion criteria (n = 4) A conference abstract (n = 1)
Articles assessed for eligibility (n = 2)
Articles excluded: Not a randomized controlled or crossover trial (n = 1) Not fulfilled the inclusion criteria (n = 5) Articles were duplicated in the search strategy for "homonymous visual field defects" (n = 10)*
Articles included in a systematic review (n = 15)
Articles included in a meta-analysis (n = 9)
NOTE: Articles excluded for reason indicated "*" are included in a systematic review and a meta-analysis and are omitted from the list of excluded articles.


A
B
C
D
Standard Error
Standardised Mean Difference
0.0
0.1
0.2
0.3
0.4
0.5
-0.5
0.0
0.5
1.0

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 6
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 7
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 7 and Appendix 1a and b
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix 1a and b
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 9
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 9
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 8 PEDro scale was uded.
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 9
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 9
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 9-10
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 9 and 11
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 9
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 10

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Not reported
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 8
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 11 and Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Appendix 2
Study characteristics	17	Cite each included study and present its characteristics.	Page 12-15, Table 1 and Table 2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 15 and Table 3
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 15
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 15-17 and Figure 2a-2d
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Not reported
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not reported
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 17 and Figure 3a-3d
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 17-20
	23b	Discuss any limitations of the evidence included in the review.	Page 20-21
	23c	Discuss any limitations of the review processes used.	Page 21
	23d	Discuss implications of the results for practice, policy, and future research.	Page 21
OTHER INFORMATION			
Registration and	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 6

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
protocol	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 6
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not reported
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 22
Competing interests	26	Declare any competing interests of review authors.	Page 22
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not reported

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Supplementary information

Full Title: The effects of rehabilitative interventions on reading disorders caused by homonymous visual field defects: A systematic review and meta-analysis focusing on improvement in reading speed

Authors: Takaya Maeyama, Hiroki Okada*, Shinya Sakai

***Corresponding author: Asst Prof Hiroki Okada**
Email: 17s3015@g.iuhw.ac.jp

Table of Contents

1. Search Strategies (Appendix 1a, 1b)

Appendix 1a. Search strategies for "homonymous visual field defects"

MEDLINE/PubMed

("Hemianopsia" [MeSH Terms] OR "hemianop*" [Title/Abstract] OR "homonymous visual field defect" [Title/Abstract] OR "homonymous visual field defects" [Title/Abstract] OR "homonymous visual field loss" [Title/Abstract]) AND ("rehabilitation" [MeSH Terms] OR "occupational therapy" [MeSH Terms] OR "therapy" [MeSH Subheading] OR "rehabilitation" [Title/Abstract] OR "training" [Title/Abstract] OR "treatment" [Title/Abstract]) AND (("randomized controlled trial" [Publication Type] OR "controlled clinical trial" [Publication Type] OR "randomized" [Title/Abstract] OR "placebo" [Title/Abstract] OR "drug therapy" [MeSH Subheading] OR "randomly" [Title/Abstract] OR "trial" [Title/Abstract] OR "groups" [Title/Abstract]) NOT ("animals" [MeSH Terms] NOT "humans" [MeSH Terms])) AND (1990/01/01:2021/12/31[Date - Entry] AND "English" [Language])

Cochrane Library

https://www.cochranelibrary.com/web/cochrane/advanced-search/search-manager?search=6982114

ClinicalTrials.gov

#1: Hemianopia OR Hemianopsia OR Hemianopsias OR Hemianopias OR hemianopic OR "homonymous visual field

#2: rehabilitation OR training OR treatment OR therapy OR Therapeutic

#3: #1 AND #2

CINAHL

(((MH "Blindness") OR (TI hemianop* OR AB hemianop*) OR (TI "homonymous visual field defect*" AND AB "homonymous visual field defect*") OR (TI "homonymous visual field loss" AND AB "homonymous visual field loss")) AND ((MH "Rehabilitation+") OR (TI rehabilitation OR AB rehabilitation) OR (TI training OR AB training) OR (TI treatment OR AB treatment) OR (TI therap* OR AB therap*))) AND ((MH randomized controlled trials OR MH double‐blind studies OR MH single‐blind studies OR MH random assignment OR MH pretest‐posttest design OR MH cluster sample OR TI (randomised OR randomized) OR AB (random*) OR TI (trial) OR (MH (sample size) AND AB (assigned OR allocated OR control)) OR MH (placebos) OR PT (randomized controlled trial) OR AB (control W5 group) OR MH (crossover design) OR MH (comparative studies) OR AB (cluster W3 RCT)) NOT ((MH animals+ OR MH (animal studies) OR TI (animal model*)) NOT MH (human)))

(continued)

ScienceDirect

(Hemianopsias OR Hemianopias OR Hemianopic OR "homonymous visual field") AND (rehabilitation OR training OR treatment OR therapy OR Therapeutic)

NOTE: The last date the abovementioned databases were searched was May 23, 2022.

Appendix 1b. Search strategies for "homonymous hemianopia"

MEDLINE/PubMed

("Hemianopsia" [MeSH Terms] OR "homonymous hemianop*" [Title/Abstract]) AND ("rehabilitation" [MeSH Terms] OR "occupational therapy" [MeSH Terms] OR "therapy" [MeSH Subheading] OR "rehabilitation" [Title/Abstract] OR "training" [Title/Abstract] OR "treatment" [Title/Abstract]) AND (("randomized controlled trial" [Publication Type] OR "controlled clinical trial" [Publication Type] OR "randomized" [Title/Abstract] OR "placebo" [Title/Abstract] OR "drug therapy" [MeSH Subheading] OR "randomly" [Title/Abstract] OR "trial" [Title/Abstract] OR "groups" [Title/Abstract]) NOT ("animals" [MeSH Terms] NOT "humans" [MeSH Terms])) AND (1990/01/01:2021/12/31[Date - Entry] AND "English" [Language])

Cochrane Library

https://www.cochranelibrary.com/web/cochrane/advanced-search/search-manager?search=7001538

ClinicalTrials.gov

#1: Hemianopia OR Hemianopsia OR Hemianopsias OR Hemianopias OR hemianopic OR "homonymous hemianopia"

#2: rehabilitation OR training OR treatment OR therapy OR Therapeutic

#3: #1 AND #2

CINAHL

(((MH "Blindness") OR (TI homonymous hemianop* OR AB homonymous hemianop*)) AND ((MH "Rehabilitation+") OR (TI rehabilitation OR AB rehabilitation) OR (TI training OR AB training) OR (TI treatment OR AB treatment) OR (TI therap* OR AB therap*))) AND ((MH randomized controlled trials OR MH double‐blind studies OR MH single‐blind studies OR MH random assignment OR MH pretest‐posttest design OR MH cluster sample OR TI (randomised OR randomized) OR AB (random*) OR TI (trial) OR (MH (sample size) AND AB (assigned OR allocated OR control)) OR MH (placebos) OR PT (randomized controlled trial) OR AB (control W5 group) OR MH (crossover design) OR MH (comparative studies) OR AB (cluster W3 RCT)) NOT ((MH animals+ OR MH (animal studies) OR TI (animal model*)) NOT MH (human)))

ScienceDirect

(Hemianopsias OR Hemianopias OR Hemianopic OR "homonymous hemianopia") AND (rehabilitation OR training OR treatment OR therapy OR Therapeutic)

NOTE: The last date the abovementioned databases were examined was August 16, 2022

2. List of Excluded Full-Text Article (Appendix 2)

Appendix 2. List of Excluded Full-Text Article (n = 15)

Reason for Exclusion	List of Studies
Not a randomized controlled trial	Bergsma DP, Elshout JA, van den Berg AV (2017) Segregation of Spontaneous and Training Induced Recovery from Visual Field Defects in Subacute Stroke Patients. Front Neurol 8:681. https://doi.org/10.3389/fneur.2017.00681 de Haan GA, Melis-Dankers BJ, Brouwer WH, Tucha O, Heutink J (2016) The Effects of Compensatory Scanning Training on Mobility in Patients with Homonymous Visual Field Defects: Further Support, Predictive Variables and Follow-Up. PLoS One 11(12). https://doi.org/10.1371/journal.pone.0166310 de Jong D, Kaufmann-Ezra S, Meichtry JR, von Arx S, Cazzoli D, Gutbrod K, Müri RM. The influence of reading direction on hemianopic reading disorders. J Clin Exp Neuropsychol 38(10):1077-1083. https://doi.org/10.1080/13803395.2016.1189884 Gall C, Silvennoinen K, Granata G, de Rossi F, Vecchio F, Brösel D, Bola M, Sailer M, Waleszczyk WJ, Rossini PM, Tatlisumak T, Sabel BA. Non-invasive electric current stimulation for restoration of vision after unilateral occipital stroke. Contemp Clin Trials 43:231-236. https://doi.org/10.1016/j.cct.2015.06.005 George S, Hayes A, Chen C, Crotty M (2011) The effect of static scanning and mobility training on mobility in people with hemianopia after stroke: a randomized controlled trial comparing standardized versus non-standardized treatment protocols. BMC Neurol 11: 1-6. https://doi.org/10.1186/1471-2377-11-87 Han Y, Ciuffreda KJ, Kapoor N (2004) Reading-related oculomotor testing and training protocols for acquired brain injury in humans. Brain Res Brain Res Protoc 14(1):1–12. https://doi.org/10.1016/j.brainresprot.2004.06.002 Schuett S, Zihl J (2013) Does age matter? Age and rehabilitation of visual field disorders after brain injury. Cortex 49(4):1001–12. https://doi.org/10.1016/j.cortex.2012.04.008

Appendix 2. (continued)

Reason for Exclusion	List of Studies
Not fulfilling the inclusion criteria	Bowers AR, Keeney K, Peli E (2014) Randomized crossover clinical trial of real and sham peripheral prism glasses for hemianopia. JAMA Ophthalmol 132(2):214–22. http://10.1001/jamaophthalmol.2013.5636 Casco C, Barollo M, Contemori G, Battaglini L (2018) Neural Restoration Training improves visual functions and expands visual field of patients with homonymous visual field defects. Restor Neurol Neurosci 36(2):275–91. http://doi.org/10.3233/RNN-170752 Cavanaugh MR, Blanchard LM, McDermott M, Lam BL, Tamhankar M, Feldon SE (2021) Efficacy of Visual Retraining in the Hemianopic Field after Stroke: Results of a Randomized Clinical Trial. Ophthalmology 128(7):1091–101. https://doi.org/10.1016/j.ophtha.2020.11.020 Elshout JA, Bergsma DP, Sibbel J, Baars-Elsinga A, Lubbers P, Van Asten F, Visser-Meily J, Van Den Berg AV (2018) Improvement in activities of daily living after visual training in patients with homonymous visual field defects using Goal Attainment Scaling. Restor Neurol Neurosci 36(1):1–12. http://doi.org/10.3233/RNN-170719 Jobke S, Kasten E, Sabel BA (2009) Vision restoration through extrastriate stimulation in patients with visual field defects: a double-blind and randomized experimental study. Neurorehabil Neural Repair ;23(3):246–55. https://doi.org/10.1177/1545968308324221 Plow EB, Obretenova SN, Fregni F, Pascual-Leone A, Merabet LB (2012) Comparison of visual field training for hemianopia with active versus sham transcranial direct cortical stimulation. Neurorehabil Neural Repair 26(6):616–26. https://doi.org/10.1177/1545968311431963 Rowe FJ, Hepworth LR, Conroy EJ, Rainford NEA, Bedson E, Drummond A, García-Fiñana M, Howard C, Pollock A, Shipman T, Dodridge C, Johnson S, Noonan C, Sackley C (2019) Visual Function Questionnaire as an outcome measure for homonymous hemianopia: subscales and supplementary questions, analysis from the VISION trial. Eye (Lond) 33(9):1485–93. https://doi.org/10.1038/s41433-019-0441-z

Appendix 2. (continued)

Reason for Exclusion	List of Studies
A conference abstract	Rowe FJ, Conroy EJ, Bedson E, Cwiklinski E, Drummond A, García-Fiñana M, Howard C, Pollock A, Shipman T, Dodridge C, MacIntosh C, Johnson S, Noonan C, Barton G, Sackley C 0.2 Clinical Trial Results – Rehabilitation and Recovery A randomized controlled trial comparing the effectiveness of prism glasses, visual search training and standard care to improve visual field for people with hemianopia. post stroke Int J Stroke Vol. 10. 111 RIVER ST, HOBOKEN 07030-5774, NJ USA: WILEY-BLACKWELL, 2015. https://doi.org/10.1111/ijs.12478

3. Forest plots for the meta-analysis (Fig. 1)

Fig. 1 a: Forest plot showing the improvement in reading speed through all rehabilitative interventions

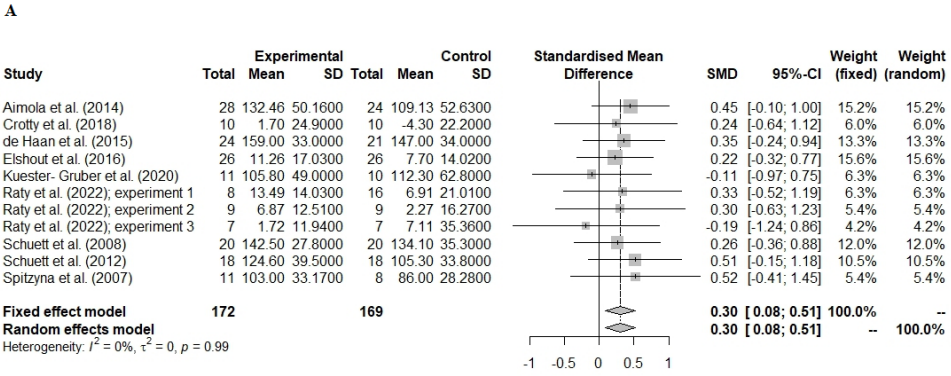


Fig. 1 b: Forest plot showing the improvement in reading speed through visual exploration training

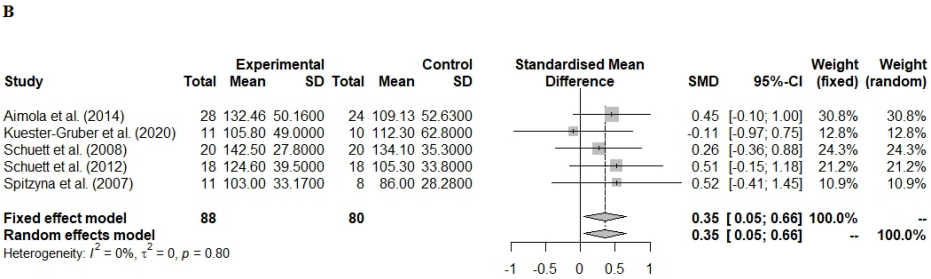


Fig. 1 c: Forest plot showing the improvement in reading speed through visual exploration training

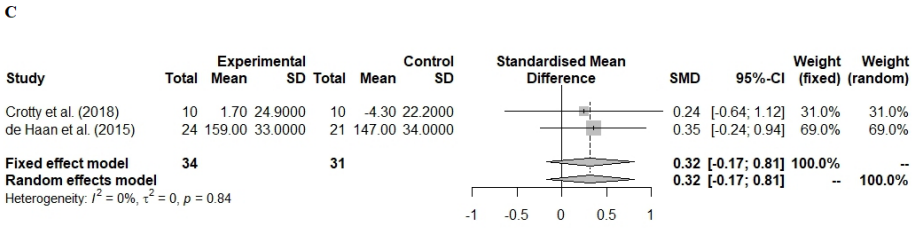


Fig. 1 d: Forest plot showing the improvement in reading speed through visual restoration therapy