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Leesproblemen bij individuen met homonieme gezichtsvelduitval

Reading difficulties in individuals with homonymous visual field defects

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Abstract

Homonymous visual field defects (HVFD) are regular consequences of acquired brain injuries, leading to contralateral visual impairment. Reading impairment is prevalent among individuals with HVFD, significantly impacting daily life and their rehabilitation process. Aiming to provide guidance for healthcare professionals and individuals affected by HVFD, this study investigated the factors influencing reading performance in individuals with HVFD. The study included 54 participants with HVFD (35 men, 19 women; average age 55.56 years). Participants underwent a comprehensive assessment, including the Visual Functioning Questionnaire 25 (VFQ-25), a subjective measure. Reading acuity, reading speed, and the number of correct words were measured objectively using the Radner reading acuity test and Radner reading chart. Quadrantanopic HVFD participants scoring significantly better on the VFQ-25 and reading speed compared to hemianopic HVFD. No significant differences in reading performance were observed between participants with left HVFD and right HVFD. This lack of distinction could possibly be attributed to differences in the underlying causes of reading difficulties specific to left HVFD and right HVFD. Significant moderate and low positive correlations were found between subjective and objective measures of reading performance in individuals with HVFD. The findings of this study offer insights into the factors that affect reading performance in individuals with HVFD. These results can guide the development of more effective, personalised rehabilitation interventions to improve reading outcomes for individuals with various types of HVFD.

Reading difficulties in individuals with homonymous visual field defects

Vision loss can be a consequence of various aetiologies, including traumatic brain injury, brain tumours, multiple sclerosis, and, most commonly, strokes (Shah et al., 2020; Zhang et al., 2006). A regular form of vision loss following acquired brain injury are homonymous visual field defects (HFVD), a partial loss of sight in both eyes contralateral to the brain damage. These defects are bilateral (uniform across both eyes) as they are caused by lesions beyond the optic chiasm, likely within the visual cortex or the geniculocalcarine tract as it approaches the visual cortex (Caplan, 2009). Homonymous hemianopia is the most frequent form of HVFD, characterised by *half blindness*, not perceiving either the right or left half of the visual field. This condition is caused by damage to the visual brain areas or the neuro-ophthalmic tract (Zhang et al., 2006). In addition to homonymous hemianopia, hemianopia can also occur after chiasmal lesions. This is referred to as bitemporal hemianopia, a loss of vision on the outer half of both the right and left eye (Fuller et al., 2010). In this study, the term *hemianopia* specifically refers to homonymous hemianopia: visual field defects on the same side of both eyes, contralateral to the brain damage. Hemianopia can affect either the left or right side of the visual field. Quadrantanopia denotes the loss of vision in a quarter of the visual field. In the case of homonymous quadrantanopia, the same upper or lower quadrant is consistently affected in both eyes. Quadrantanopia can also be crossed (one upper and one lower quarter), congruous (equally sized defects), or incongruous (unequally sized defects) (Millodot, 2018). For the purposes of this study, *quadrantanopia* refers to homonymous quadrantanopia.

The macula, the central part of the retina, is integral to colour perception, visual acuity, and high-resolution vision. This pigmented area in the central retinal region contains multiple layers of ganglion cell nuclei (Orth et al., 1977). Situated at the centre of the macula is the fovea, a dense area of photosensitive cells that enables high-resolution vision (Handa, 2012). Macular splitting occurs when HVFD divides the central vision of the macula. It is common to have a

partial preservation of this central vision. Macular sparing indicates that, despite a visual field loss, vision is retained in the middle of the visual field (Zhang et al., 2006).

Reading, an essential part of daily life, is a commonly affected function by HVFD after brain injury (Warren, 2009). Of all individuals with hemianopia, 90% have a significant reading impairment due to disruption of the foveal (point of fixation on the retina) and parafoveal (surrounds the fovea) areas of the visual field (Schuett et al., 2008). Several previous studies (Aimola et al., 2014; Horton et al., 2021; Schlaggar et al., 2007; Zihl et al., 1995) have shown that a lesion to the left occipital lobe (right HVFD) has a more pronounced effect on reading than a lesion to the right occipital lobe (left HVFD). This disparity can be attributed to several factors. Trauzettel-Klosinski and Brendler (1998) asserted that right HVFD has a more significant impairment of reading performance than left HVFD. To plan the next saccade for reading parafoveal vision on the right side is needed. Schuett et al. (2008) demonstrated that in cultures where reading proceeds from left to right, the maximum number of letters (reading span) that can be processed during a fixation (eyes focused on a single location) is larger on the right side (15 letters, approximately 5°) than on the left side of the fixation (4 letters, approximately 1.3°). Each fixation in the reading process serves as a cue for the placement of the subsequent fixation, providing a preview of the text to the right (Schotter et al., 2012). Conversely, in cultures where reading proceeds from right to left, left HVFD would likely have a more pronounced effect on reading. Loss of foveal field vision in general leads to more rightward and leftward (regressive) saccades, slows reading speed due to increased and prolonged fixations, and reduces reading accuracy, particularly in right HVFD (Trauzettel-Klosinski & Brendler, 1998). Due to the exclusion of letters within the blind visual field, individuals with HVFD may exhibit difficulties in word recognition and text reading (Zihl et al., 1995).

Research conducted by Zihl (2002) suggested that individuals with hemianopia experience more significant reading impairments than to those with quadrantanopia. This can be attributed to the fact that quadrantanopia only affects a quarter of the visual field, whereas hemianopia results in the loss of half the visual field. A general rule is that the extent of reading impairment correlates with the extent of visual field sparing (Zihl, 1995). Consequently, individuals with hemianopia typically require more reading training than individuals with quadrantanopia (Schuett, 2009).

Reading difficulties can be assessed through a variety of methods, including subjective measures such as the VFQ-25 questionnaire (Mangione et al., 1998) and the reading scale of the IVI questionnaire (Hassell et al., 2000; Lamoureux et al., 2006), as well as objective measures such as reading speed, the Radner reading acuity test, and the Radner reading chart (Radner et al., 1998). These tests are not designed to measure the exact same construct. It is challenging for subjective questionnaires and objective tests to measure the exact same component, even though all tests aim to quantify various aspects of reading performance.

Given its integral role in numerous daily activities, reading impairments associated with HVFD can significantly impact quality of life and independence. Despite spontaneous recovery is seen in at least 50% of individuals with HVFD after one month (Kedar et al., 2006; Zhang et al., 2006), the challenges associated with daily life activities and independent living can remain substantial (De Haan et al., 2015a). For example reading speed is essential for quickly identifying information, such as dialling an emergency number. Reading accuracy is crucial in many everyday tasks, including communication, financial management and medication management (Warren, 2009). The ability to read is a fundamental part of the rehabilitation process for individuals with HVFD who experience reading difficulties and seek to improve their skills, and therefore has been an important topic of scientific research. A look at current rehabilitation displays a variety of options, a recent review by Tol et al. (2024) outlines various

intervention possibilities for individuals with HVFD and reading difficulties. These strategies can be applied to everyday life. Existing treatment methods have demonstrated improvements in reading accuracy, reading speed and eye movements. However, their effectiveness in enhancing functional, reading-related tasks remains largely unexplored (Kerkhoff et al., 2024). Compensatory methods, such as adjusted saccadic behaviour, are currently the most widely used and the only empirically supported approach for individuals with visual field defects (Tol et al., 2024). Visual restitution training (Kasten et al., 1998; Sabel et al., 2000), a personalised computer software program designed for individuals with visual field defects resulting from optic nerve diseases and post-chiasmal brain lesions, has been suggested to potentially improve reading performance, among other outcomes. A study by Kuester-Gruber et al. (2020) indicates that the side of the HFVD plays a crucial role. A recently developed rotated reading training program demonstrated that individuals with left HVFD benefitted from horizontal reading training, while individuals with right HVFD demonstrated greater proficiency with vertical reading training. Notably, reading speed of individuals with HVFD after vertical training did not equal that achieved with horizontal training (Kuester-Gruber et al., 2020). A review by Pollock et al. (2011) indicated that existing evidence supporting the implementation of compensatory scanning training for individuals with HVFD to improve visual field, scanning, and reading outcomes remains limited. This highlights the need for further research to shed light on these reading challenges in individuals with HVFD and develop more effective rehabilitation interventions. A deeper understanding of the factors influencing reading performance, such as the type of HVFD, and effective measurement tools will ultimately contribute to optimizing rehabilitation options for individuals with HVFD.

The aim of this article is to study the factors that influence reading performance in individuals with HVFD. Our research questions are as follows:

a) Are there differences in reading performance between individuals with left HVFD and right HVFD?

b) Are there differences in reading performance between individuals with hemianopic HVFD and those with quadrantanopic HVFD?

c) Is there a significant correlation between objective measures of reading performance (such as reading speed, reading acuity, and the number of correct words) and the subjective experience of reading performance, as assessed by the VFQ questionnaire?

The proposed hypothesis of research question a) is that there are differences in reading capacity between individuals with left HVFD and right HVFD. Based on previous finding individuals with right HVFD are expected to exhibit poorer reading performance (as assessed by reading speed, reading acuity, number of correct words and VFQ questionnaire) compared to individuals with left HVFD. Regarding research question b, the data is expected to reveal disparities between hemianopia and quadrantanopia. We anticipate that individuals with hemianopia will exhibit poorer reading performance than those with quadrantanopia. The proposed hypothesis of research question c) is that there will not be a strong correlation between the subjective reading experience of individuals with HVFD (VFQ questionnaire) compared to the objective measurements for reading difficulties (reading speed, reading acuity, and the number of correct words).

Method

Participants

To address our research questions, data from a previous study on the effects of compensatory scanning training on mobility in individuals with HVFD was used (De Haan et al., 2015b; De Haan et al., 2016). Only pretest data from this randomised controlled trial was included. Participants were recruited from Bartiméus and Royal Dutch Visio, two leading Dutch centres of expertise for blind and partially sighted individuals, between 2010 and 2012. Upon

admission to these centres, individuals with suspected HVFD were invited to participate in the study. Those who agreed underwent standardised neuropsychological and visual assessments at Bartiméus or Royal Dutch Visio. A standardised protocol was implemented to ensure consistent testing procedures. The presence of a HVFD, restricted to one half of the visual field, was the primary inclusion criterion. Other inclusion criteria included a minimum binocular visual acuity of Snellen 0.5, non-disturbed eye and head motility, a stable ophthalmological and neurological condition, and the ability to walk at least 50 metres. To make sure only the scanning training was measured, and was not influenced by spontaneous recovery, participants were only enrolled to this project from five months on after their brain injury. Exclusion criteria were binocular visual acuity, ocular diseases affecting the visual field, neglect, insufficient Dutch language proficiency, and signs of severe physical impairments or (neuro)psychological disorders. To ensure that all participants had the cognitive capacity for informed consent, participants with a Mini-Mental State Examination (MMSE) score below 24 (out of 30) were excluded (Folstein et al.,1975).

This current study is part of a clinical trial (De Haan et al., 2015b; De Haan et al., 2016). The study protocol was approved by the Medical Research Ethics Committee of the University Medical Center Groningen (registration number METc 2010/078).The study was conducted in accordance with the 2008 Declaration of Helsinki. Written informed consent was obtained from all participants.

Materials

Questionnaire

The impact of visual field defects on participation and daily activities, such as reading, was assessed using a standardised questionnaire. The questionnaire was administered during a structured oral interview.

Visual Functioning Questionnaire (VFQ-25). The VFQ-25 is a questionnaire about the participants vision defects in combination with health related domains (Mangione et al., 1998). In the current study a Dutch version of the VFQ-25 was used (Van der Sterre et al., 2001). The participants had to assess the impact of their HVFD on e.g. social functioning, emotional well-being and activities. Questions including: "How much difficulty do you have reading ordinary print in newspapers?" and "Because of your eyesight, how much difficulty do you have finding something on a crowded shelf?". A lower VFQ-25 score indicates that the participant experiences more difficulties (Mangione et al., 2001). In this study only the domains 'VFQ vision' and 'VFQ near' are used as they are expected to have the highest influence on the participants reading skills. The 'VFQ vision' is a subjective value of the participant's eyesight and consists of two items. The 'VFQ near' is a subjective value of the participant's eyesight needed during tasks nearby and consists of six items. To address research question c), the domains 'VFQ near', 'VFQ vision', and the item 'How much difficulty do you have reading ordinary print in newspapers?' were used to provide an overview of subjective measurement at both a more general level (VFQ vision), and a more specific level (VFQ near and newspaper item). Items are rated as follows: 1) No difficulty at all, 2) A little difficulty, 3) Moderate difficulty, 4) Extreme difficulty, 5) Stopped doing this because of your eyesight, 6) Stopped doing this for other reasons or not interested in doing this. For this study, only data from participants who selected options 1, 2, 3, 4, or 5 were included, as option 6 does not provide relevant information on acquired reading difficulties.

Reading tests

Two reading tests were administered where participants could use their own glasses or lenses. The Radner reading acuity test required participants to read a text (around 400 words) out loud, while using their own preferred reading distance. After this, participants were asked two questions about the content. Correct answers and reading speed were implemented as

outcome measures. Additionally the Radner reading chart was administered (Maaijwee et al., 2007), individuals have to read the sentences on this chart out loud, while the size of the text is decreasing. The chart is 40 cm away from the participant. Minimal readable text size and the average reading speed (sentences 3 to 7) were used as outcome measures. The Radner is a reliable measure of reading acuity and reading speed (Brussee et al., 2015). Repeated measurements studies show high validity en reproducibility (Brussee et al., 2014).

Procedure

The assessments were conducted by the department of Clinical and Developmental Neuropsychology of the University of Groningen at the University Medical Center Groningen, the Netherlands. Participants were tested individually in Dutch by assessors who were blinded to the group allocation. The results were kept private and did not affect training or rehabilitation.

Data Analysis

The analysis for this current study was conducted using SPSS Statistics 28. To address research questions a) and b), we first examined the assumptions underlying parametric testing. Our study employed a significance level of .05 to evaluate statistical significance. The normality assumption indicates that the collected data follows a normal distribution, which is crucial for parametric testing (Kim et al., 2019). Assumptions were assessed using the Shapiro-Wilk test, Kolmogorov-Smirnov test and Levene's test (see Appendix A). If the group data met all four of the assumptions, an independent samples t-test would be used to compare the two independent groups (Kim et al., 2019). If any assumptions were violated, the Mann Whitney U test, a nonparametric test for comparing two independent groups, would be used (Mann et al., 1947).

To assess research question c), outcome measures 'Radner reading chart speed', 'Radner reading acuity speed' and 'Radner reading acuity correct' would be reversed, as lower scores indicate poorer performance at these variables. However, a lower VFQ score indicates

better performance. Spearman's correlation would be used, as parametric test assumptions were not met due to an ordinal level of testing. According to the rule of thumb (Hopkins et al., 1997), a Spearman's rho correlation coefficient score of 0.00 to 0.10 is considered insubstantial, 0.10 to 0.30 low, 0.30 to 0.50 moderate, 0.50 to 0.70 high, 0.70 to 0.90 very high, and 0.90 to 1.00 is considered a nearly perfect correlation.

Results

This study included data from 54 individuals with HVFD, consisting of 35 men and 19 women. The average age of the participants at the time of assessment was 55.56 years old (SD=11.88), with ages ranging from 27 to 74. An overview of the dependent variables used in this study, along with their descriptive statistics, is presented in Table 1.

Table 1

Descriptive statistics of raw scores VFQ vision, VFQ near, Radner reading chart size, Radner reading chart speed, Radner reading acuity speed and Radner reading acuity correct.

	N	*Mean (Standard deviation)*	*Min*	*Max*
VFQ newspaper item[a]	54	1.94 (0.98)	1.00	4.00
VFQ vision[a]	54	59.26 (14.32)	30.00	90.00
VFQ near[a]	54	68.36 (17.76)	25.00	100.00
Radner reading chart size[b]	52	0.08 (0.14)	-0.20	0.40
Radner reading chart speed[b]	52	149.10 (32.23)	73.40	225.30
Radner reading acuity speed[b]	51	132.23 (29.14)	63.00	190.00
Radner reading acuity correct[b]	52	1.58 (0.57)	0.00	2.00

[a]Subjective data. [b]Objective data.

To answer research questions a) and b) a Shapiro-Wilk test was used (n<50, Table 2) to test for normality. In research question a) the independent groups are categorised as 'left HVFD' (n=37) and 'right HVFD' (n=17). Results of the independent samples t-test and Mann Whitney U test indicate there is no significant difference between left-sided HVFD and right-sided HVFD (Table 3). In research question b) the independent groups are 'hemianopia' (n=43) and 'quadrantanopia' (n=11). The independent samples t-test results show that there is a significant difference between Quadrantanopic HVFD and Hemianopic HVFD at 'VFQ vision'

(t(52) = 3.14, p = .001), 'Radner reading chart speed' (t(50) = 1.76, p = .042), and 'Radner reading acuity speed' (t(49) = 2.19, p = .017). The outcome measure 'VFQ near' also shows significant differences between Quadrantanopic HVFD and Hemianopic HVFD measured by the Mann Whitney U test (U = 129.00, p = .020). In all these cases, participants with Quadrantanopic HVFD scored significantly better on reading performance than participants with Hemianopic HVFD.

Table 2

Descriptive statistics left/right HVFD and hemianopic/quadrantanopic HVFD.

	Side HVFD:		*Type HVFD:*	
	Left	*Right*	*Hemianopia*	*Quadrantanopia*
VFQ vision	M=58.78(14.64) n=37	M=60.29(13.97) n=17	M=56.40(13.02) n=43	M=70.45(14.22) n=11
VFQ near	M=67.79(17.80) n=37	M=69.61(18.15) n=17	Mdn=25.00 n=43	Mdn=37.27 n=11
Reading chart size	Mdn=26.18 n=36	Mdn=27.22 n=16	Mdn=26.38 n=41	Mdn=26.95 n=11
Reading chart speed	M=150.84(30.82) n=36	M=145.16(35.94) n=16	M=145.11(32.71) n=41	M=163.96(26.62) n=11
Reading acuity speed	M=136.07(29.82) n=36	M=123.84(26.57) n=16	M=127.97(29.50) n=41	M=149.70(20.70) n=11
Reading acuity correct	Mdn= 27.89 n=36	Mdn=23.38 n=16	Mdn=25.65 n=41	Mdn=29.68 n=11

Note. Mdn: Mean rank Mann Whitney U test. M(sd): Mean and standard deviation independent samples t-test.

Table 3

Differences between left/right HVFD and differences between hemianopic/quadrantanopic HVFD.

	Side HVFD: left vs. right	*Type HVFD: hemianopia vs. quadrantanopia*
VFQ vision	t(52)=-.36, p=.361	t(52)=3.14, p=**.001*** **
VFQ near	t(52)=-.35, p=.365	U=129.00, p=**.020***
Radner reading chart size	U=276.50, p=.813	U=220.50., p=.907
Radner reading chart speed	t(50)=.58, p=.281	t(50)=1.76, p=**.042***
Radner reading acuity speed	t(49)=1.40, p=.083	t(49)=2.19, p=**.017***
Radner reading acuity correct	U=238.00, p=.245	U=190.50, p=.357

-T(df): Independent samples t-test.
-U: Mann Whitney U test.

-Significant: *p<.050, **p<.010, ***p<.001

Spearman's correlation coefficient findings to address research question c) indicate moderate and significant positive correlations between 'VFQ newspaper item' and both 'Radner reading chart speed' (r(50) = .355, p = .010, see Table 4) and 'Radner reading acuity speed' (r(49) = .337, p = .016). Additionally, 'VFQ domain near' exhibited moderate and significant positive correlations with 'Radner reading chart speed' (r(50) = .363, p = .008) and low but significant positive correlations with 'Radner reading acuity speed' (r(49) = .290, p = .039). Finally, the study results show a moderate and significant positive correlation between 'VFQ domain vision' and 'Radner reading acuity speed' (r(49) = .429, p = .002).

Table 4

Correlation between objective reading data and the subjective experience of reading ability

	VFQ newspaper item	*VFQ near*	*VFQ vision*
Radner reading chart size	r=.059; p=.677	r=.127; p=.368	r=.088; p=.533
Radner reading chart speed	**r=.355; p=.010****	**r=.363; p=.008****	r=.210; p=.135
Radner reading acuity speed	**r=.337; p=.016***	**r=.290; p=.039***	**r=.429; p=.002****
Radner reading acuity correct	r=.215; p=.126	r=.153; p=.279	r=.050; p=.725

-Spearman's rho correlation coefficient
-Significant: *p<.050, **p<.010, ***p<.001

Discussion

The purpose of this article was to study the factors that influence reading performance in individuals with HVFD. The set of research questions aimed to examine differences in reading performance based on type of HVFD (left or right, and hemianopia or quadrantanopia), and whether objective measures of reading performance correlated with subjective experiences of reading performance. The findings of this study suggest that individuals with left HVFD and with right HVFD exhibit comparable reading performance. Significant differences were found between individuals with quadrantanopic HVFD and hemianopic HVFD on several measures (VFQ vision, VFQ near, Radner reading chart speed and Radner reading acuity speed), with quadrantanopic HVFD individuals scoring higher indicating better reading performance.

Additionally, moderate and low positive correlations were found between subjective questionnaires (VFQ domains vision, near and newspaper item) and objective measurements of reading speed (Radner reading chart speed and Radner reading acuity speed).

The results of the current study indicate no significant differences between individuals with left HVFD and right HVFD in their reading performance, as assessed by measures of reading speed, reading acuity and questionnaires. These findings contradict our initial hypothesis and previous research findings suggesting inferior reading performance for individuals with right HVFD (Aimola et al., 2014; Horton et al., 2021; Trauzettel-Klosinski & Brendler, 1998; Zihl et al., 1995). As noted by Schlaggar et al. (2007), the neural system underlying reading is predominantly left-lateralised, encompassing the parietal, occipitotemporal, and frontal regions of the left hemisphere. Lesion studies have demonstrated that the ventral left prestriate cortex plays a crucial role in word recognition. Damage in this region results can result in error-prone and slowed down reading, a condition known as alexia (Behrmann et al., 1998). Therefore, damage to the left hemisphere in general, beyond the visual field defect, could have a more severe negative impact on reading than damage to the right hemisphere. Although no significant differences were found in this study, this does not necessarily mean that there are no differences in reading performance of individuals with left HVFD or right HVFD, or the underlying causes of these reading problems. One possible underlying cause could be that individuals with left HVFD are (objectively and subjectively) slower at reading due to a greater difficulty in finding the beginning of the next sentence (Horton et al., 2021). On the other hand, individuals with right HVFD could experience the same amount of reading problems attributed to a completely different cause. For example, individuals with right HVFD could have more difficulties with reading speed, as they cannot read ahead (Zihl et al., 1995). With every fixation on the targeted word, the right visual field provides a preview of the upcoming text, offering insight into where to place the following

fixation, which enhances reading speed (Schotter et al., 2012). The diverse underlying causes of reading difficulties could potentially impact the outcome of this study and explain the lack of a discernible difference in reading performance between individuals with left HVFD and right HVFD. We also checked to establish there is no impingement effect of the quadrantanopic data interfering with the hemianopic data, and therefore did not cause measurable significant differences. Generating a second data group of exclusively individuals with hemianopic HVFD revealed still no significant differences between reading performance in individuals with left and right hemianopic HVFD. The findings of this study indicate that within our group of participants, individuals with left HVFD and right HVFD experience comparable levels of reading difficulties. Both groups may benefit from rehabilitation to enhance their reading performance, although the specific training approaches may need to be tailored to address the underlying causes of their difficulties.

The current study demonstrates that individuals with quadrantanopic HVFD exhibit significantly superior reading performance compared to those with hemianopic HVFD, supporting previous findings by Blaylock et al. (2016), Schuett (2009), Zihl (2000), among others, and confirming the hypothesis put forth in this study. This suggests that the amount of required rehabilitation training is also greater for individuals with hemianopic HVFD than for those with quadrantanopic HVFD.

The current study found significant moderate and low correlations between subjective questionnaires and objective measurements of reading performance in individuals with HVFD. However, no significant correlations were noted between subjective measurements and other objective measures, such as ‘Radner reading chart size’ and ‘Radner reading acuity correct’. This suggests that an individual's subjective experience of daily life reading problems is moderately to low correlated with the objective testing measurements of reading speed. There were no big discrepancies found between the correlations of objective measures with VFQ

domains ‘near’, ‘vision’, and ‘newspaper’ item. Except for no significant correlation between ‘VFQ vision’ and ‘Radner reading chart speed’, which did correlate significantly with ‘VFQ near’ and ‘VFQ newspaper item’. The current literature lacks studies reporting reliability and validity scores for the subjective measurement by the VFQ. Had such information been available, a good reliability and validity score would have increased the likelihood of finding stronger correlations between the VFQ and objective reading measures. A strong correlation between a subjective questionnaire and an objective measurement could indicate that the questionnaire might be a viable alternative to objective assessments administered by healthcare providers. Additionally, if an intervention successfully increases reading speed, it is likely to positively impact individuals' subjective experiences of daily life challenges. Although this study found only moderate and low correlations between the previously mentioned domains of the VFQ and objective measurements, better scores on the VFQ domains generally correspond to better performance on objective assessments. Therefore, the VFQ could potentially be used alongside objective measurements. Various other subjective methods have been developed to assess, among other factors, reading performance. Studies by Kuester-Gruber et al. (2020) and Selivanova et al. (2019) made use of the reading scale of the Impact of Visual Impairment Questionnaire (IVI; Hassell et al., 2000; Lamoureux et al., 2006). A study by Aimola et al. (2014) used the reading scale of the Visual Impairments Questionnaire (VIQ; Kerkhoff et al., 1994). Studies by Hayes et al. (2012), Plow et al. (2012), Rowe et al. (2017), and Daibert-Nido et al. (2021) used the reading scale of the Veterans Affair Low-Vision Visual Functioning Questionnaire (VA LV VFQ-48; Stelmack et al., 2004). A reading and visual exploration Questionnaire (without title) by Kerkhof et al. (1990) was used in studies by Schuett et al. (2008) and Schuett et al. (2012). A recent review by Tol et al. (2024) suggests interviews or a Goal Attainment Scale (GAS; Grant & Ponsford, 2014) to provide individuals the possibility for outcomes relevant to them, as there are no reading questionnaires validated for individuals

with HVFD. To draw more definitive conclusions regarding the reliability and validity of subjective versus objective tests in measuring reading performance, additional research studies are required. Moreover, it is essential to include data from a healthy control group for both objective and subjective measures. This would allow for a more comprehensive comparison and strengthen the overall validity of our findings.

Limitations

All test results should be interpreted with caution as only limited data (54 participants) is used in this research to objectify reading performance. We acknowledge that this study did not account for several factors influencing reading performance, including the time elapsed since the trauma that caused the HVFD. As in general reading performance improves with increasing time since onset (Trauzettel-Klosinski & Brendler, 1998). Assuming that one group consisted entirely of individuals who had experienced trauma one year ago, while the other group consisted of individuals who had experienced trauma only five months ago, this difference in time elapsed could have influenced reading performance. Individual characteristics such as level of education, which are known to affect reading performance, were not considered (Brussee et al., 2016). A higher level of education could enhance reading performance and influence our study results. Factors related to the reading tasks, such as reading distance or whether the text was read aloud or silently, were also not omitted in the current study (Brussee et al., 2016). Finally, the presence or extent of macular sparing, a key factor for reading in individuals with HVFD (Horton et al., 2021), was not assessed. Horton et al. (2021) acknowledged that macular sparing is associated with an individual's reading ability. There are two contradictive theories regarding macular sparing. The Split Fovea Theory proclaims that visual stimuli left of the fixation point are projected onto the right hemisphere and visual stimuli right of the fixation point are projected onto the left hemisphere (Brysbaert, 2004). On the other hand, the Bilateral Projection Theory states that words presented within the fovea are projected

simultaneously onto both hemispheres. The parafoveal area, where readers extract information from the next word or two, has a contralateral projection (Bunt et al., 1977). Following the Split Fovea Theory and the Bilateral Projection Theory, it could be suggested that individuals with macular sparing, where the middle of the visual field is still intact (Horton et al., 2021), would have less difficulties regarding reading speed. Half of the text surrounding the fixation point is missing in case of macular splitting. This harmed macular function reduces reading speed and the number of characters per fixation (Leff et al., 2000). This declines reading performance and the effortless joy of reading drastically (Horton et al., 2021). Macular sparing may influence the outcomes obtained in the current study. If one of the compared groups had a higher proportion of participants with macular sparing, it could lead to higher reading scores in that group, creating a potential bias in the findings.

Recommendations for future research

For future studies a distinction between inferior and superior quadrantanopic HVFD could be made. Levine et al. (2005) state that as a general rule, individuals perform better on reading performance to some degree when stimuli are in the inferior visual hemifield rather than in the superior visual field. It would be valuable to explore whether individuals with superior quadrantanopic HVFD might experience fewer reading difficulties, compared to those with inferior quadrantanopic HVFD.

To ensure the validity of the study results, it is important to screen for neglect. Neglect, an attention disorder, can often be mistaken for (or co-exist with) HVFD (Hreha et al., 2024). Extinction of the contra lesional side can occur in three sensory modalities: processing auditory, touch and visual information (Coslett, 2018). Neglect is often more persistent and severe following a right cerebral lesion than after a left cerebral lesion. Most theories attribute neglect as a failure to direct attention to the contralateral hemispace (Heilman, 2011). An individual with neglect on the left or right side can sometimes be mistaken for having a left or right

hemianopia (Kooistra et al., 1989), as both groups can have trouble noticing objects on the affected side. Neglect can also exist simultaneously with a HVFD, these individuals have a visual field loss and an attention deficit. Both visual field defects and neglect can affect the performance of daily life activities (Hreha et al., 2024). In rehabilitation it has been noticed that individuals with neglect are more likely to struggle with learning new strategies. Individuals with neglect are less likely to acquire techniques for reading with HVFD. Neglect has a poor functional outcome prognosis, all current therapies remain effectively dissatisfying (Jehkonen et al., 2006). Recommended is a multifactorial approach in clinical testing (Lindell et al., 2007). In the current study neglect was excluded based on Line Bisection, drawings, Rey Complex Figure and the Balloons test. For future research optional tests to provide more information about neglect could be the Star cancellation task, who appears to be the one of the most sensitive tests (Halligan et al., 1989, Lindell et al., 2007). To also distinguish different forms of neglect, the Apples test could be used. In addition, the Apples test seems to be a useful predictor of functional outcome (Bickerton et al., 2011).

Given the substantial impact of macular function on reading ability, future research should distinguish between individuals with macular sparing and those with macular splitting. Further recommendations for clinical practice include conducting studies with larger experimental and control groups. Additionally, it is advisable for future research to assess the reliability and validity of subjective measures, like the VFQ used in this study.

Conclusion

In conclusion, the results of the current study indicate no significant differences between individuals with left HVFD or right HVFD in their reading performance (as assessed by reading speed, reading acuity, number of correct words and VFQ questionnaire). A possible explanation for this lack of distinction could be attributed to potential differences in the underlying factors influencing reading ability specific to left HVFD and right HVFD, however these different

underlying causes may counterbalance any inherent disparities. The data used in this study does show significant better reading performance for individuals with quadrantanopic HVFD compared to individuals with hemianopic HVFD. Significant moderate and low positive correlations have been found in this study between subjective and objective measurement of reading performance in individuals with HVFD. The findings of this study contribute to a better understanding of the factors influencing reading performance in individuals with HVFD. These results can inform the development of more effective and tailored rehabilitation interventions for healthcare professionals to improve reading performance in individuals with various types of HVFD.

Appendix A

Test assumptions

The normality assumption indicates that the collected data follows a normal distribution, which is crucial for parametric testing (Kim et al., 2019). To asses this assumption the Shapiro-Wilk test is applied to group samples smaller than 50, while the Kolmogorov-Smirnov is used to asses group samples greater than or equal to 50. For both tests a significance level greater than or equal to .05 indicates no significant deviation from a normal distribution. (Field et al., 2018). The assumption of equal variance implies that the variances of the samples and their corresponding populations are equal (Nahm et al., 2016). A Levene's test score greater than or equal to .05 meaning there is no significant difference between the group variances. The third assumption is random sampling and independent measurements (Field et al., 2018). An interval level of measurement is the final assumption (Cohen et al., 1969). If any of the assumptions cannot be met, a nonparametric test will be used. Unlike parametric tests, nonparametric tests rely on the ranks or minus/plus signs of the data, rather than the actual data values (Nahm et al., 2016).

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