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Understanding reading complaints in people with Parkinson's disease: a cross-sectional study

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Abstract

Difficulty reading is a common complaint in people with Parkinson's Disease (PD), which negatively impacts quality of life. However, little is known about reading complaints in people with PD. This study attempts to demonstrate which functional impairments may contribute to reading complaints in people with PD, and which advice and aids may be helpful in alleviating reading complaints.

The Cerebral Visual Complaints questionnaire (CVCq) was administered to 74 people with PD. Based on the reading item of the CVCq, the sample was divided into two groups; 55 people with frequent and 19 people with infrequent reading complaints. All individuals underwent an extensive assessment of visual, visual perceptual and cognitive functions, the results of which were compared between the two groups. Furthermore, 60 participants received occupational therapy for reading complaints. The effectiveness of advice and aids was analyzed.

Visual and visual perceptual functions that demonstrated the largest difference between the two groups were contrast sensitivity, reading acuity, visual acuity, lateralized attention/spatial cognition and visual motor speed/mental flexibility. Cognitive functions showed only small differences. Effective advice and aids were mostly targeted to the functions which showed the largest differences between the groups.

Some specific functional impairments seem to contribute more to reading complaints than others. This is supported by the rehabilitation often initiated at these functions. In clinical practice, these functions should be the first to be assessed. However, we cannot rule out that other functions contribute to reading complaints as well. Therefore, rehabilitation should always be tailored to the individual.

Keywords. Parkinson Disease; Reading complaints; Reading difficulties; Visual rehabilitation; Quality of life

Introduction

Parkinson's disease (PD) is a common neurodegenerative disorder worldwide (Amsterdam UMC, 2019). It manifests itself through the more familiar motor symptoms, such as bradykinesia, rigidity and tremors (Parkinson, 2002). However, PD also presents itself with a variety of non-motor symptoms. A few of these non-motor symptoms include visual, visual perceptual, and cognitive impairments (Ekker et al., 2017; Jehangir et al., 2018; Meireles & Massano, 2012).

In recent years, there has been increasing focus on visual complaints in people with PD in scientific and clinical practice. Studies have shown, using newly developed questionnaires, that visual complaints are more prevalent in people with PD than in people without PD (Borm et al., 2020; Van der Lijn et al., 2022; Van der Lijn et al., in press). The variety of visual complaints in people with PD is high. Functional related complaints include unclear vision, reduced contrast, double vision, visual hallucinations and trouble with depth perception. Activity related complaints refer to e.g., difficulties in reading, driving, watching television and computer tasks (Borm et al., 2020; Van der Lijn et al., in press). These complaints negatively affect the daily life of people with PD. In addition, it is known that with increasing age, disease duration and disease severity, the frequency and severity of visual complaints increase (Van der Lijn et al., in press).

One of the most commonly reported visual complaints in people with PD is difficulty reading. More than 50% of people with PD reported reading complaints and difficulty reading seems to be an exclusive complaint in people with PD compared to people without PD (Archibald et al., 2011; Biousse et al., 2004; Borm et al., 2020; Kwan et al., 2022; Urwyler et al., 2014; Van der Lijn et al., 2022; Van der Lijn et al., in press). Reading complaints are primarily described by people with PD in terms of movement of words and letters, blurred vision, diplopia, and visual discomfort (Bargagli et al., 2020; Urwyler et al., 2014).

The process of reading involves a complex interaction of visual, visual perceptual and cognitive functions. Reading starts with the distal stimulus, the word/phrase that someone wants to read, that already contributes to how it is perceived. For example, words/phrases with less contrast (i.e., dark gray letters on light gray background) are more difficult to read than words/phrases with optimal contrast (i.e., black letters on white background) and also the print size of a text has an influence on reading (Whittaker & Lovie-Kitchin, 1993). Next, visual functions determine how the distal stimulus is projected onto the retina. Two common examples of visual functions involved in reading are visual acuity, the degree to which the lens can project a sharp image of a word onto the retina and eye movements, including saccades, fixations and convergence, which are responsible for seeing a particular word in focus (Rayner, 1998). After the word enters the retina, the information reaches the visual cortex through electrical impulses, which includes the decoding of the visual input. The encoding into meaningful concepts of the information obtained is dependent on many brain regions responsible for processing visual information (Yeatman & White, 2021). Reading and understanding is therefore dependent on a variety of visual perceptual and cognitive functions. Visual perceptual functions that play a role in reading include visual span, the number of letters that can be read without moving the eyes, and visual crowding, properly identifying a word/letter when it is surrounded by other words/letters (Joo et al., 2018; Kwon, Legge & Dubbels, 2007). Examples of cognitive functions include attention, which plays a critical role in processing the information read, and working memory, which holds and integrates the information of a word while reading ongoing phrases (Commodari & Guarnera, 2005; Savage, Lavers & Pillay, 2007). So, as many different functions are involved in the process of reading, difficulty reading can occur in case of impairments in a wide variety of functions which can make reading a demanding and fatiguing process (Griffing & Franz, 1896).

Besides the examples just mentioned in describing the process of reading, other visual, visual perceptual, and cognitive impairments that may contribute to reading difficulties can be found in previous literature. Various visual function deficits have been associated with reading difficulties in other populations. Reduced visual acuity and contrast sensitivity, which appears to increase with age, are related to reading difficulties and decreased reading speed (Chung, 2020; Owsley, 2016; Raasch & Rubin, 1993; Whittaker & Lovie-Kitchin, 1993). Furthermore, loss of visual field and disorders of eye movements, including hypometric saccades, convergence insufficiency and longer fixation duration have been associated with reading difficulties (Chung, 2020; Rayner, 2009; Underwood, Hubbard & Wilkinson, 1990; Whittaker & Lovie-Kitchin, 1993). A deficit in these functions can also contribute to reading difficulties in people with PD. Abnormal eye movements can lead to slower reading in people with PD (i.e., hypometric saccades, longer fixation duration, convergence insufficiency, binocular dysfunction and smooth pursuit; Gottlob et al., 2004; Archibald et al., 2011; Jehangir et al., 2018; Kwan et al., 2022; Yu et al., 2016). Furthermore, reading speed appears to be negatively affected by decreased contrast sensitivity and visual acuity in people with PD (Kwan et al., 2022; Moes & Lombardi, 2009). A decreased blink rate is also common in people with PD, which is associated with dry eyes and unclear vision when reading (Biousse et al., 2004; Savitt & Mathews, 2018).

In addition, several impairments of visual perceptual functions are related to reading difficulties. Even though studied in children, reading difficulties were found to relate to impairments in visual search, visual spatial attention, visual short-term memory, and dynamic visual perception (Franceschini et al., 2021; Gavril, Rosan & Szamosközi, 2021; Huestegge et al., 2012). Furthermore, visual crowding and visual span play a major role in reading (Chung, 2020; Gori & Facoetti, 2015; Pelli et al., 2007; Rayner, 2009; Yeatman & White, 2021). Although these functions seem to have an impact on reading, they have rarely been studied in

people with PD and reading difficulties. In both people with and without PD, visuospatial planning is important in reading speed (Jehangir et al., 2018). Visuospatial planning becomes even more important for reading speed when there is an increased visual crowding (irregular spacing between letters) and an increased number of words (Jehangir et al., 2018; Yu et al., 2016). Other visual perceptual functions found in people with PD that are not studied in the context of reading but are consistent with the visual perceptual functions that play an essential role in reading are visual scanning/visual search, visual spatial attention, and visual short-term memory (Crucian et al., 2010; Rolinski et al., 2016; Zokaei et al., 2014). Due to the relationship of these visual perceptual functions with reading, it is expected that reading in people with PD might be negatively affected by these functional impairments.

Moreover, cognitive impairment is associated with reading difficulties. Children with reading disability showed lower scores in attentional, planning, simultaneous and successive processes than in children without reading disability (Elwan, Gaballah & Khalifa, 2019). Furthermore, working memory, with high demands of attentional control and verbal information processing, nonlinguistic nonverbal reasoning ability and executive functioning are associated with reading comprehension (Carretti et al., 2009; Georgiou & Das, 2016; Van Wingerden et al., 2018). A variety of impairments in these cognitive functions are also associated with reading difficulties in people with PD. Lower scores for executive functions, attention and language correlated with slower reading speed in people with PD (Stock et al., 2020). Reading comprehension in PD is related to verbal memory, especially in texts with high-level language (Murray & Rutledge, 2014). People with PD have also been found to exhibit a hyperpriming effect, an impairment in ignoring irrelevant words, due to impaired inhibitory control in reading (Marí-Beffa et al., 2005).

In summary, studies have identified a variety of functional impairments that may contribute to reading difficulties in people with PD. However, studies often included only a

small number of subjects, have focused mainly on specific aspects of reading (i.e., reading speed or reading comprehension) and have not fully addressed self-reported reading complaints in people with PD. Further, only one or few specific functions have been studied, and the extent to which a wide variety of visual, visual perceptual, and cognitive functions contribute to reading complaints in PD has not been investigated. To improve rehabilitation and therefore the quality of life of people with PD, a more detailed insight into reading complaints and the functions that may contribute to reading complaints in people with PD is required.

Therefore, the first aim of our study is to provide more insight into the reading complaints of people with PD. Very few studies have addressed the difficulties that people with PD experience during reading. We anticipate recovering reading complaints from previous studies about movement of words and letters, blurred vision, diplopia, and visual discomfort, as well as discover possible additional reading complaints.

Second, our study attempts to create a more accurate account of functional impairments that contribute to reading complaints using a variety of visual, visual perceptual, and cognitive tests. Based on previous studies, visual functions we at least expect to be related to reading complaints are visual acuity, contrast sensitivity, blink rate and different eye movements. Commonly mentioned visual perceptual functions we expect to contribute to reading complaints are visual crowding, visual search, visual memory, and visual attention. Cognitive functions we expect to be related to reading complaints are executive functions (i.e., planning and inhibition control), attention, and verbal memory. Due to the multifaceted impairments associated with reading difficulty in people with PD in previous studies, a multifaceted outcome is also expected in the current study, with multiple divergent impairments in all three domains contributing to reading complaints. Since a large test battery is used to obtain a proper overview of possible impairments that may be related to visual complaints in people with PD, additional impairments not described in the literature may also emerge.

An additional aim of this study is to identify which advice and aids are effective for people with PD in order to alleviate their reading complaints, potentially make future rehabilitation processes more effective and thus increase the quality of life of people with PD. Little is known about how to effectively target reading complaints in people with PD. Markowitz, Daibert-Nido & Markowitz (2018) described a number of rehabilitation techniques to improve reading skills in people with age-related macular degeneration, including eyewear (e.g., prism glasses), training devices (e.g., magnifications), training material (e.g., good contrast, lighting, seating, font), training for better oculomotor control (e.g., flashlight technique which trains smooth pursuit and accurate eye movements) and perceptual training (e.g., practice reading over several sessions). Also, in children with dyslexia, visual training, including filters for reading, magnification of letters and larger letter spacing appears to increase the visual span and can lead to faster and better word recognition (Bucci, 2021, Zhu et al., 2019). Whether these training methods are also effective in people with PD is not known. There are some ways suggested to improve visual disorders in people with PD, which may also lead to better reading behavior. People with PD may benefit from occupational therapies, such as the use of reading stands (Savitt & Mathews, 2018). In relation to double vision and convergence insufficiency, prism glasses are recommended to shift the peripheral target to the center of the visual field (Savitt & Mathews, 2018). However, negative aspects of the everyday use of prism glasses are that prism glasses are sometimes too heavy, that the quality of the image is not always sufficient, that they sometimes create a blind spot and that the adaptation of the prisms cannot always be adjusted properly (Sato et al., 2014; Savitt & Mathews, 2018).

In this study, occupational therapy reports/medical files will be used to demonstrate which advice and aids have been effective in alleviating reading complaints in the context of visual rehabilitation. It is expected to find results consistent with those found in previous literature, including the use of reading stands, text magnification, contrast adjustment, and for

example, an adjusted seating position during reading. However, as the rehabilitation options investigated so far are not all scientifically supported in people with PD, other effective advice and aids may also be found.

Method

Participants/Procedure/Design

Seventy-four participants with idiopathic PD were recruited between August 2017 and June 2022 at the Royal Dutch Visio, an expertise center for blind and visually impaired people. During the admission interview at Royal Dutch Visio, participants completed a semi-structured questionnaire about their visual complaints. Based on the extent to which people reported reading complaints on the questionnaire, they were divided into two groups: people with PD and frequent reading complaints who reported to experience reading complaints often/always (RC+; n = 55) and people with PD and infrequent reading complaints who reported to experience reading complaints never/hardly or sometimes (RC-; n = 19). A cross-sectional design was used to compare the groups.

A part of the standard care at Royal Dutch Visio was the assessment of various visual, visual perceptual and cognitive functions according to pre-established protocols. Visual function measurements were performed by an orthoptist; visual perceptual and cognitive functions were administered by a neuropsychologist. The performance of all functional tests took a total of about four hours.

In order to help people with their visual complaints, suggestions for advice and aids are made by a multidisciplinary team based on the complaints and disorders of each individual. An occupational therapist presented the advice and aids to the respective individual and it is evaluated together whether these could be useful to alleviate visual complaints. In the present study, provided occupational therapy was evaluated to determine which of the applied advice and aids were effective and which were not in reducing reading complaints in people with PD.

All participants were informed in advance about the course and purpose of the study and gave written consent for the collection and use of their pseudonymized data.

Materials

Demographic and disease-related data

Demographic data of each participant were obtained from Royal Dutch Visio dossiers. Disease-related data were taken from information of a treating neurologist and ophthalmologist provided with the referral to Royal Dutch Visio. Demographic and disease-related data included gender, age, and level of education, disease duration, Hoehn and Yahr stage (H&Y) for disease severity, current daily levodopa dose (LEDD), and neurological, ophthalmological, or psychiatric comorbidity (Hoehn & Yahr, 1967). If the participants had not visited an ophthalmologist before, an ophthalmologic examination was performed at Royal Dutch Visio.

Cerebral Visual Complaints questionnaire (CVCq)

The original version of the CVCq is based on the Cerebral Vision Screening Questionnaire (CVSq), which consists of 10 questions to measure visual complaints in people with acquired brain injury (Kerkhoff, Schaub & Zihl, 1990). The CVCq is an expanded Dutch version of the CVSq, for a more thorough assessment of subjective visual complaints at a functional level, such as unclear vision and sensitivity to light, as well as an activity level, such as having difficulty reading and driving. This questionnaire was edited using questions from the Screening Visual Complaints questionnaire (SVCq) to specifically address visual complaints in people with PD and Multiple Sclerosis (Huizinga et al., 2020). The CVCq includes 43 semi-structured items. Our study addresses question 15 and 16 of the CVCq. Question 15 focuses on the frequency of reading complaints which can be rated using a 3-point Likert scale (‘never/hardly’, ‘sometimes’, ‘often/always’). This is followed by a question asking for a more detailed description of the reading complaint, with four preset response options (dancing letters, skipping words or parts of sentences in the left or right margin, having

difficulty finding the beginning of a line, having difficulty continuing on the same line) and the option to provide one's own descriptions. Multiple responses were allowed for this question. Yet, there is no information on the validity and reliability of the CVCq. The CVCq can be found in Appendix A.

Visual, visual perceptual and cognitive function tests

Sixteen visual function tests, eleven visual perceptual function tests and four cognitive function tests were administered in both groups. The visual function test for eye motility was measured monocularly in both eyes. All other visual functions were measured at binocular level. To measure color vision, the Farnsworth was performed. If this test showed intact functioning, the Lanthony also had to be performed to classify the function as 'not impaired', so that subtle impairments in color vision would not be overlooked. If the Farnsworth was performed with the conclusion 'impaired', then the classification was made without performing the Lanthony. Visual perceptual functions were examined using the DiaNAH battery on a 24" Wacom tablet, programmed by Metrisquare Diagnosis (de Vries, et al., 2018; www.diagnosis.com). Tests used to examine cognitive functions were all non-visual. The cognitive test battery also included two tests to measure symptoms of depression and anxiety. A detailed description of the measured functions, including tests, conditions, and classifications of impairments can be found in Table 1.

Table 1
Visual, visual perceptual and cognitive function tests

Function	Test and condition	Classification of impairment
Visual functions		
Visual acuity	ETDRS 2000 chart[1] (500 lux, distance 4 meter)	<0.8 Snellen (Logmar <0.1)
Contrast sensitivity	Gecko[2] or Vistech[3] (500 lux, distance 3 meter)	Peak CS log <1.40

Reading acuity	Laboratory of Experimental Ophthalmology[4] (LEO), 9 reading charts	<Binocular visual acuity/2
Visual field	Esterman[5] or Goldmann (Isopter V-4[e])	Presence of absolute scotoma
Color vision	Farnsworth D-15[6] (500 lux), Lanthony D-15[7] (500 lux)	Impaired
Stereopsis	Orthoptist assessment	Absent
Pupillary light reflex	Swinging light test[8] (10 and 500 lux)	Impaired
Eye alignment	Cover/uncover test	Not aligned/tropias distant and/or near
Eye motility	Orthoptist assessment, following a light in eight different directions	Impaired in one or both eyes
Saccades	Orthoptist assessment, alternately looking at one of two objects, which were 40 cm apart, horizontally and vertically	Impaired horizontally and/or vertically
Smooth pursuit	Orthoptist assessment, following a light horizontally and vertically up to 40° from the center	Impaired horizontally and/or vertically
Convergence	Orthoptist assessment	Up to >10cm, or absent
Nystagmus	Orthoptist assessment	Present
Blink rate	Orthoptist assessment	Low
Optokinetic nystagmus	Orthoptist assessment, horizontally and vertically	Impaired horizontally and/or vertically
Vestibulo-ocular reflex	Orthoptist assessment, horizontally and vertically	Impaired horizontally and/or vertically
Visual perceptual functions[9]		
Figure-ground segmentation	L-POST Figure Ground[10]	<17th percentile
Shape perception	L-POST Shape Ratio[10]	<17th percentile
Movement perception	L-POST Motion Detection[10]	<17th percentile
Visual motor speed	Trail Making Test A[11]	<17th percentile
Visual motor speed/mental flexibility	Trail Making Test B[11]	<17th percentile
Visual motor speed/mental flexibility	Trail Making Test B/A[11]	<17th percentile
Lateralized visual attention/spatial cognition	Bells Test[12]	<17th percentile
Visual constructive skills	Taylor Complex Figure[13]	<17th percentile
Visual search/grouping	Dot Counting Task[14]	≤10th percentile
Visual load/crowding	Crowding Task	≤10th percentile
Simultanagnosia	Birthday Party Test[15]	<17th percentile
Visual spatial memory	Corsi Block Tapping Task[16]	<17th percentile
Object perception	Silhouettes[17]	<17th percentile
Cognitive functions		

Short term memory (span capacity), focused/sustained attention	Digit Span - forward[18]	<14-19th percentile
Working memory, focused/sustained attention	Digit Span - backward[18]	<14-19th percentile
Working memory, focused/sustained attention	Digit Span - sorting[18]	<14-19th percentile
Short term/working memory, focused/sustained attention	Digit Span - total[18]	<14-19th percentile
Verbal memory - encoding	15 Words Test - encoding[19]	<17th percentile
Verbal memory - retention	15 Words Test - recall[19]	<17th percentile
Verbal fluency/executive functioning	Letter Fluency[20]	<17th percentile
Anxiety symptoms	HADS Anxiety[21]	Raw score >11
Depression symptoms	HADS Depression[21]	Raw score >11

Note. [1]Ferris et al. (1982); [2]Kooijman et al. (1994); [3]Ginsburg (1984); [4]Kooijman & Beerthuizen (1996); [5]Esterman (1982); [6]Farnsworth (1957); [7]Lanthony (1978); [8]Yari et al. (2018); [9]de Vries et al., (2018); [10]Torfs et al. (2014); [11]Reitan (1985), [12]Gauthier, Dehaut & Joanette (1989); [13]Taylor (1969); [14]Boone, Lu & Herzberg (2002); [15]de Vries et al. (2022); [16]Kessels et al. (2000); [17]Warrington & James (1991); [18]Saan & Deelman (1986); [19]Wechsler (2008); [20]Schmand, Groenink & Van den Dungen (2008); [21]Spinhoven et al. (1997)

Analyses

This article is written in accordance with the STROBE reporting guidelines for observational studies (Ghaferi, Schwartz & Pawlik, 2021). The STROBE checklist for cross-sectional studies can be found in Appendix B. The software program IBM SPSS 29 is used for statistical analyses (IBM Corp., 2022).

Missing data of visual, visual perceptual and cognitive function tests

An overview of the missing data per variable can be found in Appendix C. Missing data can be explained by several possible reasons, including loss of concentration or fatigue of the participants during the task, difficulties in understanding the task in order to implement it validly, or aborted tests due to time constraints. Furthermore, unreliable data from visual field tests were excluded (i.e., in case of artifacts or loss of fixation). The frequency of missing data for the color vision tests can be explained by restrictions imposed by COVID-19. In these cases, no corrections or estimations of these data were made, and therefore missing variables were excluded pair-wise from the analyses.

Demographic and disease-related data

To exclude the possibility that the differences between RC+ and RC- were due to factors other than reading complaints, differences in demographic (sex, age, and level of education) and disease-related characteristics (disease duration, H&Y stage, LEDD, neurological, ophthalmological, or psychiatric comorbidity) between the two groups were analyzed. An alpha <.05 was considered to be significant. A Chi-Squared test for categorical variables was done on level of education and presence of any ophthalmological condition. Due to violation of the assumption of the Chi-square test (more than 20% of the cells have an expected value of less than 5), group differences in sex and presence of severe neurological conditions were examined by Fisher's Exact Test (2x2 crosstabs) and group differences in H&Y stage by Fishers-Freeman-Halton Exact test (2x4 crosstabs) (Kim, 2017). Effect sizes (ES) for sex, presence of severe neurological condition and presence of any ophthalmological condition were calculated by Phi (small: 0.1, medium: 0.3, large: 0.5), and for level of education (df = 2) and H&Y stage (df = 3) by Cramer's V (df = 2, small: 0.07, medium: 0.21, large: 0.35; df = 3, small: 0.06, medium: 0.17, large: 0.29) (Kim, 2017). Group differences in age were analyzed using an independent t-test and the ES Hedges' g (small: 0.2, medium: 0.5, large: 0.8) (Cohen, 1988). The Shapiro-Wilk test showed a violation of the assumption of normal distribution for the variables disease duration ($W = 0.92$, $p < .01$) and LEDD ($W = 0.88$, $p < .01$) (Shapiro & Wilk, 1965). Therefore, the Mann-Whitney U nonparametric test was performed with the ES Cohens' d (small: 0.2, medium: 0.5, large: 0.8) (Cohen, 1988). No severe psychiatric comorbidities were reported in both groups, so no comparison analyses were performed.

Description of reading complaints

The semi-closed reading item of the CVCq was analyzed for all participants who 'sometimes/often/always' experienced reading complaints using descriptive statistics. The frequency of the four preset response options were examined. Spontaneous responses, which

could be added in addition to the four preset response options, were divided into categories. Complaints whose content was similar formed a category. After categorizing the complaints, frequencies of the categories were calculated and presented using histograms.

Relations between reading complaints and visual, visual perceptual and cognitive functions

In order to compare two groups, a group with PD and frequent reading complaints, RC+ (often/always) and a group with PD and infrequent reading complaints, RC- (never/hardly, and sometimes) were used. In a cross-sectional design, results of all tests were compared between RC+ and RC- to determine to what extent impairments in the three domains (visual, visual perceptual, cognitive) contribute to reading complaints in people with PD. To calculate the mean, standard deviation and range of the test results for each group, raw scores were used in most cases. For functions without raw scores, classifications were used to calculate the mean, standard deviation and range. A 0/1 classification (0 = no impairment, 1 = impaired) was used for the variables visual field, color vision, stereopsis, pupillary light reflex, eye motility, convergence, nystagmus and blink rate. A 0/1/2 classification was applied for the functions eye alignment (0 = no impairment, 1 = not aligned/tropias distant or near, 2 = not aligned/tropias distant and near), eye motility (0 = no impairment, 1 = impaired in one eye, 2 = impaired in both eyes), saccades, smooth pursuit, optokinetic nystagmus, and vestibulo-ocular reflex (0 = no impairment, 1 = impaired horizontally or vertically, 2 = impaired horizontally and vertically). Based on the mean scores, group differences between RC+ and RC- on all visual, visual perceptual, and cognitive tests were determined using ES. To provide a bias correction to Cohen's d for small group sizes, ES Hedges' g was calculated (small: 0.2, medium: 0.5, large: 0.8) with the corresponding 95% confidence intervals (95% CIs) (Cohen, 1988; Hedges & Olkin, 2014). Furthermore, the overall ES was calculated for each domain (visual, visual perceptual and cognitive functions). For this purpose, the individual functions per domain were weighted, taking missing data (see Appendix C) into account by multiplying the ES, lower and

upper CI by the number of present data per function. The sum of the ES, lower and upper CIs of all functions was then divided by the total sample size. Using Hedges' g and the 95% CIs, forest plots were created for all variables and the three overall ES. In addition, all variables were classified as 'impaired' and 'not impaired' to calculate the percentages of impaired scores for each group per variable. The cut-off scores for the classification per variable can be found in Table 1.

Description of advice and aids for reading complaints

All participants with PD who received occupational therapy to alleviate reading complaints were included. All occupational advice and aids, including the effectiveness for each participant, were extracted from the occupational therapy reports/medical files. Advice and aids were considered effective if reading complaints could be reduced. Advice and aids were sorted into categories based on similarities in content and were evaluated using frequency analysis.

Results

Demographic and disease-related data

Table 2 shows the demographic and disease-related data of the total group and the two separate groups, as well as differences in demographic and disease-related data between the groups. A detailed summary of ophthalmological comorbidities can be found in the Appendix D. No significant differences in demographic and disease-related data were found between RC+ and RC-, and most ES were small. The difference in age showed a medium effect (g = -0.48, p = 0.08) and in H&Y stage a large effect (V = 0.25, p = 0.27).

Table 2

Demographic and disease-related data of people with PD with frequent and infrequent reading complaints

	Total PD group	RC+	RC-	p-value[a]	Effect size[b]
N	74	55	19		
Sex (female; %, n)	25.68%, 19	29.09%, 16	15.79%, 3	0.36	0.13
Age (years; M ± SD)	72.03 ± 7.73	72.75 ± 8.48	69.95 ± 4.58	0.08	-0.48
Level of education[c] (%, n)				0.99	0.02
Low	14,86%, 11	14.54%, 8	15.79%, 3		
Medium	33.78%, 25	32.72%, 18	36.84%, 7		
High	45.95%, 34	45.45%, 25	47.36%, 9		
Missing	5.41%, 4	7.27%, 4	0.0%, 0		
Disease duration (years; M ± SD); missing (%, n)	8.98 ± 6.39; 12.16%, 9	8.53 ± 6.00; 14.55%, 8	10.17 ± 7.37; 5.26%, 1	0.49	-0.09
H&Y stage (%, n)				0.27	0.25
1	4.05%, 3	1.81%, 1	10.52%, 2		
2	41.89%, 31	38.18%, 21	52.63%, 10		
3	32.43%, 24	34.54%, 19	26.31%, 5		
≥4	10.81%, 8	12.72%, 7	5.26%, 1		
Missing	10.81%, 8	12.72%, 7	5.26%, 1		
LEDD[d] (mg; M ± SD); missing (%, n)	1085.27 ± 666.91; 18.92%, 14	1065.30 ± 699.15; 16.36%, 9	1150.89 ± 566.11; 26.32%, 5	0.52	-0.08
Presence of severe neurological condition (%, n)	16.22%, 12	16.36%, 9[e]	15.79%, 3[f]	>0.99	0.01
Presence of severe psychiatric condition (%, n)	0.0%, 0	0.0%, 0	0.0%, 0	-	-
Presence of any ophthalmological condition (%, n)	50.00%, 37	52.73%, 29	42.11%, 8	0.43	0.09

Note. H&Y = Hoehn and Yahr staging (Hoehn & Yahr, 1967); LEDD = Levodopa equivalent daily dose; M = mean; mg = milligram; n = number; PD = Parkinson's disease; RC+ = people with frequent reading complaints (often/always); RC- = people with infrequent reading complaints (never/hardly/sometimes); SD = standard deviation

[a] Group differences in sex and presence of severe neurological conditions were examined by Fisher's Exact Test, age by a t-test, level of education and presence of any ophthalmological condition by a Chi-Square test, disease duration and LEDD by a Mann-Whitney U test and H&Y stage by a Fishers-Freeman-Halton Exact test

[b] Effect sizes for sex, presence of severe neurological condition and presence of any ophthalmological condition were calculated by Phi, for age by Hedges' g, for level of education and H&Y stage by Cramer's V and for disease duration and LEDD by Cohens' d

[c] Categorization based on the International Standard Classification of Education (ISCED) (UNESCO Institute for Statistics, 2012)

[d] LEDD calculated according to protocol of Tomlinson et al. (2010)

[e] Transient ischemic attack (n = 1), cerebrovascular accident (n = 3), Parkinson's disease

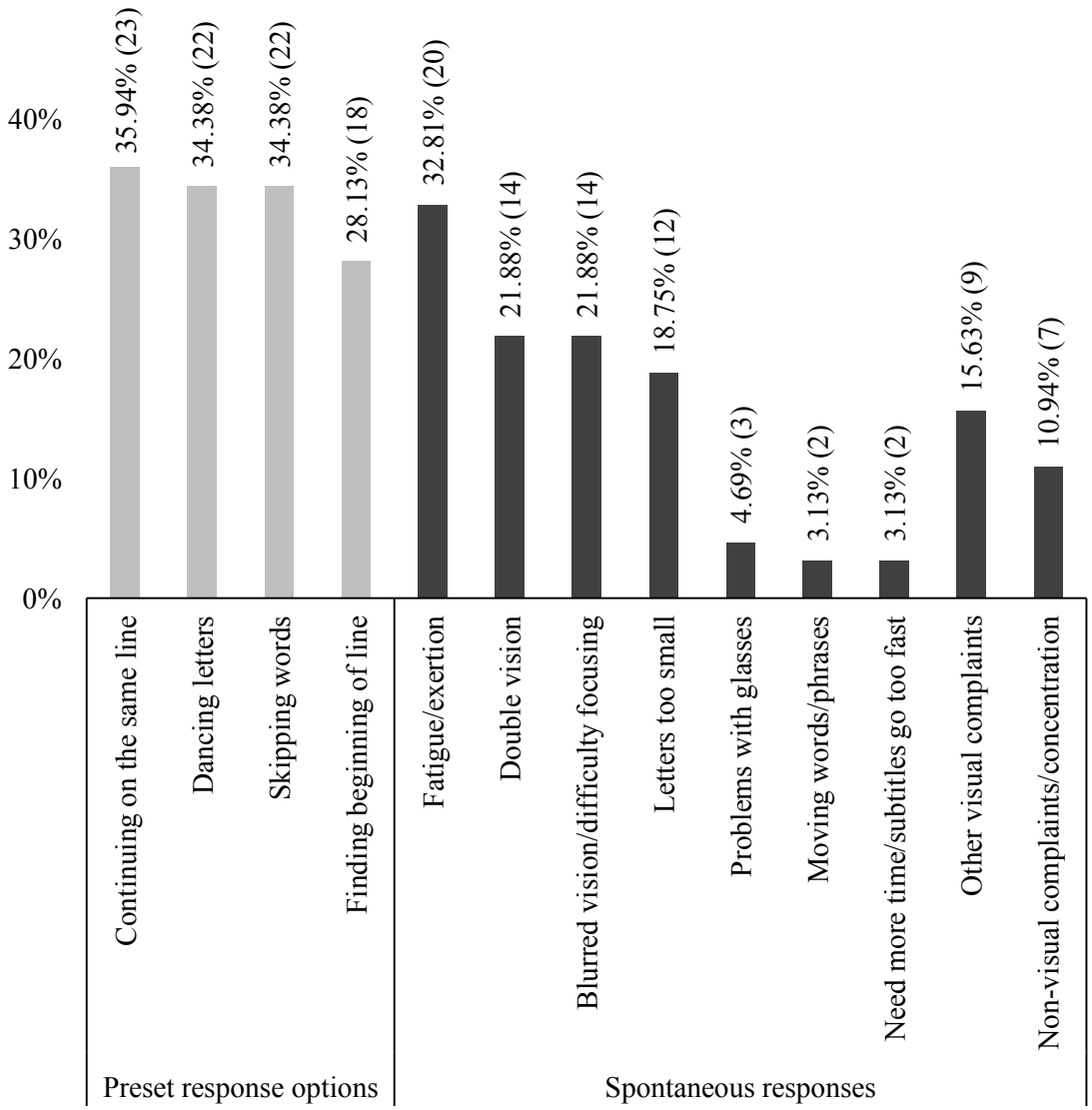
dementia (n = 2), thalamotomy (n = 1), dementia lewy body (n = 2)
[f] Parkinson's disease dementia (n = 2), dementia syndrome (n = 1)

Description of reading complaints

Descriptions of reading complaints were collected from 64 participants (see Figure 1). One participant from RC+ did not complete the semi-closed reading item of the CVCq, and was therefore removed from this analysis. Three of four preset response options (dancing letters, skipping words and having difficulty continuing reading on the same line) were reported more frequently than the spontaneous descriptions of reading complaints.

In order to evaluate added descriptions of reading complaints of the participants, nine categories were formed from spontaneously reported complaints. The most frequently mentioned spontaneous reading complaint and also more frequent than one of the preset response options (finding beginning of the line) was feeling fatigued/exerted during/after reading, followed by having double vision and blurred vision/difficulty focusing. The least frequently mentioned complaints were the perception of moving words/phrases, a lack of time/too fast subtitles and problems with glasses.

Figure 1
Description of reading complaints in people with PD based on the CVCq (%(N))



Note. Participants were allowed to give multiple responses; the category 'other complaints' contains visual complaints that did not fit into other categories, including 'painful eyes', 'I read bit by bit; in pieces', 'small membranes for my eyes', 'watery eyes', 'd and b are hard to distinguish', 'unstable image', 'sometimes I linger in one place, and read again', 'don't get full words in view', 'there is a shadow behind the letters', 'constriction in view'

Relations between reading complaints and visual, visual perceptual and cognitive functions

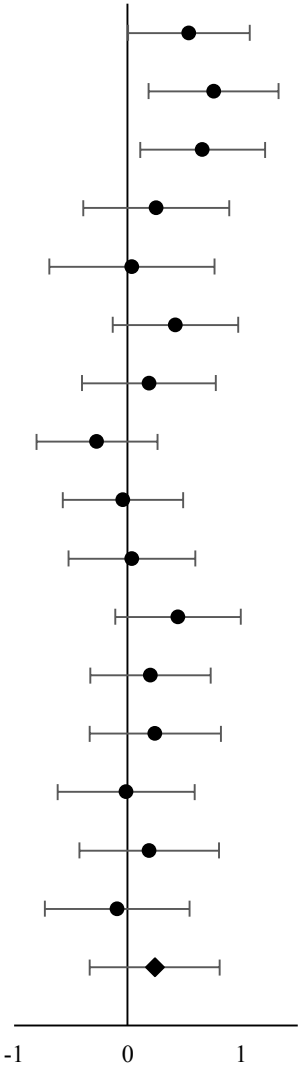
An overview of the results of all measured functions and the overall ES of the three domains can be found in Table 3. Visual functions that demonstrated the largest difference with poorer functioning in RC+ and medium ES were contrast sensitivity (g = 0.76, 95% CI [0.19,

1.33]), reading acuity (g = 0.66, 95% CI [0.11, 1.21]) and visual acuity (g = 0.54, 95% CI [0.01, 1.07]). For contrast sensitivity, 17.31% of RC+ and 0.00% of RC- showed impairment. For reading acuity, 67.27% of RC+ and 64.71% in RC- and for visual acuity, 41.82% in RC+ and 11.11% in RC- demonstrated impaired scores. The overall ES of the visual functions was small (g = 0.24, 95% CI [-0.33, 0.80]). The visual perceptual functions that showed the largest differences with poorer functioning in RC+ and medium ES were lateralized attention/spatial cognition (g = 0.58, 95% CI [0.05, 1.11]) and visual motor speed/mental flexibility (g = 0.56, 95% CI [-0.01, 1.12]). For lateralized attention/spatial cognition, 45.10% of RC+ and 15.79% of RC- showed impairment. For visual motor speed/mental flexibility, 85.37% of RC+ and 64.71% of RC- demonstrated impaired scores. The overall ES of the visual perceptual functions was small (g = 0.23, 95% CI [-0.31, 0.76]). Cognitive functions showed only small ES with more impairments in RC+, with a small overall ES (g = 0.15, 95% CI [-0.44, 0.74]). The CI bounds are generally all wide and cross 0. The only functions where the CI bounds do not exceed 0 are contrast sensitivity, reading acuity, visual acuity and lateralized attention/spatial cognition (and hardly for visual motor speed/mental flexibility). RC+ demonstrated poorer functioning than RC- on 29 of 38 tests.

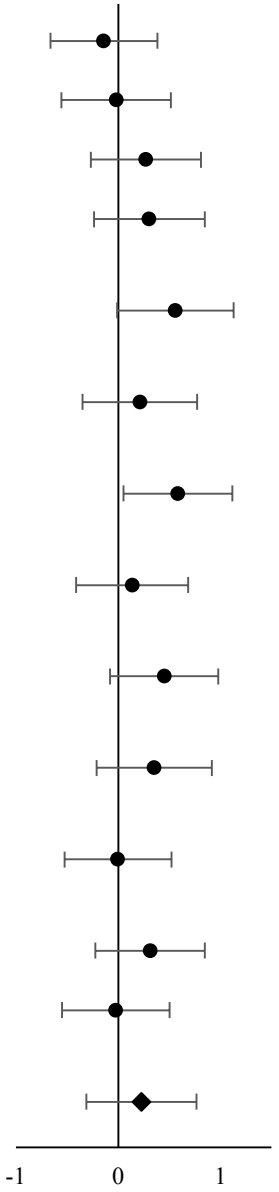
Table 3

Comparison of visual, visual perceptual, and cognitive functions between people with PD with frequent and infrequent reading complaints

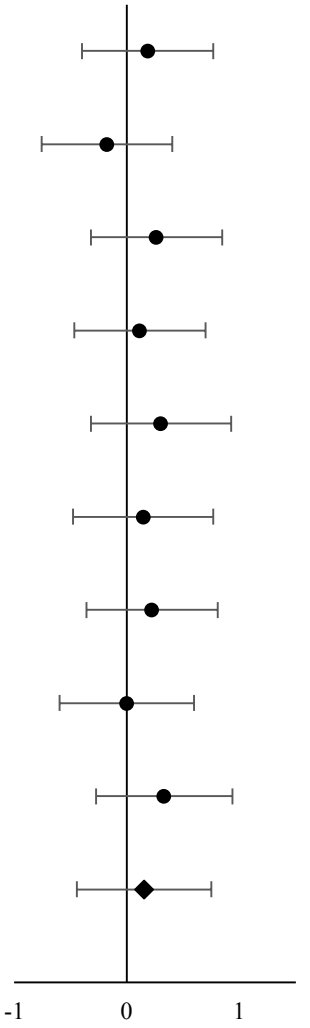
	PD RC+		PD RC-		ES Hedges' g (95% CI)	Forest plots
	Mean ± SD (range)	Impaired (%, n)	Mean ± SD (range)	Impaired (%, n)		
Visual functions						
Visual acuity	0.19 ± 0.23 (0.00 - 1.05)	41.82%, 23	0.08 ± 0.10 (0.00 - 0.40)	11.11%, 2	0.54** (0.01; 1.07)	
Contrast sensitivity	1.73 ± 0.40 (0.37 - 2.27)	17.31%, 9	2.01 ± 0.17 (1.74 - 2.23)	0.00%, 0	0.76** (0.19; 1.33)	
Reading acuity	0.34 ± 0.13 (0.05 - 0.70)	67.27%, 37	0.42 ± 0.11 (0.25 - 0.63)	64.71%, 11	0.66** (0.11; 1.21)	
Visual field	0.17 ± 0.38 (0.00 - 1.00)	16.67%, 5	0.08 ± 0.28 (0.00 - 1.00)	7.69%, 1	0.25 (-0.39; 0.89)	
Color vision	0.32 ± 0.48 (0.00 - 1.00)	31.82%, 7	0.30 ± 0.48 (0.00 - 1.00)	30.00%, 3	0.04 (-0.69; 0.77)	
Stereopsis	0.38 ± 0.49 (0.00 - 1.00)	37.50%, 18	0.18 ± 0.39 (0.00 - 1.00)	17.65%, 3	0.42* (-0.13; 0.97)	
Pupillary light reflex	0.03 ± 0.16 (0.00 - 1.00)	2.63%, 1	0.00 ± 0.00 (0.00 - 0.00)	0.00%, 0	0.19 (-0.40; 0.78)	
Eye alignment	0.56 ± 0.78 (0.00 - 2.00)	38.46%, 20	0.78 ± 0.88 (0.00 - 2.00)	50.00%, 9	-0.27 (-0.80; 0.26)	
Eye motility	0.25 ± 0.62 (0.00 - 2.00)	15.38%, 8	0.28 ± 0.67 (0.00 - 2.00)	16.67%, 3	-0.04 (-0.57; 0.49)	
Saccades	1.16 ± 0.93 (0.00 - 2.00)	64.00%, 32	1.13 ± 0.96 (0.00 - 2.00)	62.50%, 10	0.04 (-0.52; 0.59)	
Smooth pursuit	1.44 ± 0.82 (0.00 - 2.00)	79.17%, 38	1.06 ± 0.90 (0.00 - 2.00)	64.71%, 11	0.44* (-0.11; 0.99)	
Convergence	0.31 ± 0.47 (0.00 - 1.00)	31.48%, 17	0.22 ± 0.43 (0.00 - 1.00)	22.22%, 4	0.20 (-0.33; 0.73)	
Nystagmus	0.04 ± 0.21 (0.00 - 1.00)	4.44%, 2	0.00 ± 0.00 (0.00 - 0.00)	0.00%, 0	0.24 (-0.34; 0.82)	
Blink rate	0.56 ± 0.50 (0.00 - 1.00)	56.41%, 22	0.57 ± 0.51 (0.00 - 1.00)	57.14%, 8	-0.01 (-0.62; 0.59)	
Optokinetic nystagmus	0.37 ± 0.73 (0.00 - 2.00)	21.95%, 9	0.23 ± 0.60 (0.00 - 2.00)	15.38%, 2	0.19 (-0.43; 0.80)	
Vestibulo-ocular reflex	0.13 ± 0.41 (0.00 - 2.00)	10.26%, 4	0.17 ± 0.39 (0.00 - 1.00)	16.67%, 2	-0.09 (-0.73; 0.54)	
Overall effect size					0.24 (-0.33; 0.80)	



	PD RC+		PD RC-		ES Hedges' g (95% CI)	Forest plots
	Mean ± SD (range)	Impaired (%, n)	Mean ± SD (range)	Impaired (%, n)		
Visual-perceptual functions						
Figure-ground segmentation	3.52 ± 1.37 (0.00 - 5.00)	44.00%, 22	3.32 ± 1.57 (0.00 - 5.00)	47.37%, 9	-0.14 (-0.66; 0.38)	
Shape perception	4.41 ± 1.02 (0.00 - 5.00)	12.24%, 6	4.39 ± 0.98 (2.00 - 5.00)	22.22%, 4	-0.02 (-0.55; 0.52)	
Movement perception	4.08 ± 1.33 (0.00 - 5.00)	31.25%, 15	4.44 ± 1.29 (1.00 - 5.00)	16.67%, 3	0.27 (-0.27; 0.81)	
Visual motor speed	95.95 ± 70.03 (29.60 - 315.50)	58.70%, 27	71.96 ± 95.64 (27.40 - 448.80)	33.33%, 6	0.30* (-0.24; 0.84)	
Visual motor speed/mental flexibility	259.99 ± 154.89 (48.60 - 612.40)	85.37%, 35	178.96 ± 110.58 (65.60 - 448.10)	64.71%, 11	0.56** (-0.01; 1.12)	
Visual motor speed/mental flexibility	3.60 ± 2.04 (0.00 - 10.00)	68.29%, 28	3.20 ± 1.27 (1.00 - 5.50)	64.71%, 11	0.21 (-0.35; 0.77)	
Lateralized visual attention/spatial cognition	25.53 ± 10.07 (0.00 - 35.00)	45.10%, 23	30.74 ± 3.56 (21.00 - 35.00)	15.79%, 3	0.58** (0.05; 1.11)	
Visual constructive skills	25.10 ± 10.78 (0.00 - 36.00)	53.19%, 25	26.53 ± 8.92 (5.00 - 35.00)	58.82%, 10	0.14 (-0.41; 0.69)	
Visual search/grouping	10.88 ± 3.02 (0.00 - 13.00)	58.82%, 30	12.16 ± 2.09 (4.00 - 13.00)	31.58%, 6	0.45* (-0.08; 0.97)	
Visual load/crowding	4.88 ± 3.48 (0.00 - 10.00)	19.05%, 8	6.12 ± 3.46 (0.00 - 10.00)	17.65%, 3	0.35* (-0.21; 0.91)	
Simultanagnosia	19.96 ± 6.87 (4.00 - 35.00)	45.10%, 23	19.95 ± 7.89 (6.00 - 32.00)	57.89%, 11	-0.00 (-0.52; 0.52)	
Visual spatial memory	3.82 ± 1.56 (0.00 - 6.00)	29.41%, 15	4.28 ± 0.96 (3.00 - 6.00)	27.78%, 5	0.31* (-0.22; 0.85)	
Object perception	4.94 ± 1.96 (1.00 - 10.00)	27.66%, 13	4.89 ± 1.63 (2.00 - 8.00)	26.32%, 5	-0.02 (-0.55; 0.51)	
Overall effect Size					0.23 (-0.31; 0.76)	



	PD RC+		PD RC-		ES Hedges' g (95% CI)	Forest plots
	Mean ± SD (range)	Impaired (%, n)	Mean ± SD (range)	Impaired (%, n)		
Cognitive functions						
Short term memory (span), focused/sustained attention	7.74 ± 2.24 (4.00 - 14.00)	18.60%, 8	8.13 ± 1.51 (5.00 - 11.00)	6.67%, 1	0.19 (-0.40; 0.77)	
Working memory, focused/sustained attention	6.81 ± 1.72 (4.00 - 11.00)	20.93%, 9	6.47 ± 2.45 (2.00 - 12.00)	33.33%, 5	-0.18 (-0.76; 0.40)	
Working memory, focused/sustained attention	5.19 ± 2.07 (0.00 - 10.00)	51.16%, 22	5.73 ± 2.05 (2.00 - 8.00)	40.00%, 6	0.26 (-0.32; 0.84)	
Short term/working memory, focused/sustained attention	19.74 ± 5.03 (10.00 - 33.00)	27.91%, 12	20.33 ± 5.14 (10.00 - 28.00)	33.33%, 5	0.12 (-0.47; 0.70)	
Verbal memory - encoding	25.15 ± 9.95 (8.00 - 47.00)	79.49%, 31	28.15 ± 9.28 (17.00 - 44.00)	76.92%, 10	0.30* (-0.32; 0.92)	
Verbal memory - retention	4.41 ± 2.52 (0.00 - 11.00)	83.78%, 31	4.77 ± 2.35 (2.00 - 10.00)	76.92%, 10	0.14 (-0.48; 0.77)	
Verbal fluency/executive functioning	25.55 ± 12.71 (1.00 - 63.00)	71.43%, 30	28.33 ± 11.19 (11.00 - 54.00)	46.67%, 7	0.22 (-0.36; 0.81)	
Anxiety symptoms	6.36 ± 3.30 (1.00 - 16.00)	4.76%, 2	6.36 ± 2.62 (2.00 - 12.00)	7.14%, 1	0.00 (-0.60; 0.60)	
Depression symptoms	7.10 ± 3.49 (1.00 - 16.00)	11.90%, 5	5.93 ± 3.45 (1.00 - 14.00)	7.14%, 1	0.33* (-0.27; 0.93)	
Overall effect size					0.15 (-0.44; 0.74)	



Note. ** ES ≥ 0.50; * ES ≥ 0.30; CI = Confidence interval; ES = effect size; HADS = Hospital Anxiety and Depression Scale; PD = Parkinson's disease; RC+ = people with frequent reading complaints (often/always); RC- = people with infrequent reading complaints (never/hardly/sometimes); SD = standard deviation

Description of advice and aids for reading complaints

Participants in both RC+ and RC- were able to receive occupational therapy for reading complaints based on their request for help during the admission interview. There were participants from RC+ who did not receive occupational therapy (because of e.g., being content to read less, finding own solutions, deterioration of health) and there were participants from RC- who did receive occupational therapy (participants may still have some reading complaints). A total of 60 participants were included in this analysis (47 from RC+ and 13 from RC-). Advice and aids provided were sorted into ten categories (see Table 4). Since data was collected from rehabilitation, not all advice and aids listed were applied to every participant. Therefore, percentages in Table 4 do not add up to 100 percent and show only the advice and aids that have been applied.

Table 4 shows that the advice and aids that are most frequently recommended and applied are increasing task lightning, enlarging the reading material by using various magnification aids, and using e-readers, tablets and computers (e.g., to optimize text formatting). Furthermore, reading cards to cover part of the text to promote focus and reduce visual distraction, spoken alternatives (e.g., spoken subtitles), and new glasses with optimal correction to increase visual acuity are frequently recommended. Most advice and aids are considered effective rather than ineffective. The advice and aids that are more often described as ineffective than effective are the least advised (e.g., magnifying glass in only one participant).

Table 4

Provided effective and ineffective advice and aids for reading complaints in people with PD

Categories	Advice	Aids	Effective (%, n)	Ineffective (%, n)
Lighting/illumination				
	Increase task lighting	Task lamp/task lighting	46.67%, 28	6.67%, 4
	Reduce light oversensitivity	Awning	1.67%, 1	-
Magnifying				
	Magnify		43.33%, 26	3.33%, 2
	Magnify	Magnifying lamp	10.00%, 6	3.33%, 2
	Magnify	Screen magnifier	6.67%, 4	1.67%, 1
	Magnify	Magnifying glasses	1.67%, 1	-
	Magnify	Magnifying glass	-	1.67%, 1
Electronic aids/displays				
	Optimize text formatting	E-reader/tablet/computer	40.00%, 24	10.00%, 6
	Increase line spacing	E-reader/tablet/computer	13.33%, 8	3.33%, 2
	Increase contrast	E-reader/tablet/computer	10.00%, 6	-
	Increase display brightness	E-reader/tablet/computer	1.67%, 1	-
	Increase display resolution	E-reader/tablet/computer	1.67%, 1	-
	Make letters bold	E-reader/tablet/computer	1.67%, 1	-
	Zoom in	E-reader/tablet/computer	-	1.67%, 1
Promote focus/less visual distraction				
	Cover surrounding text	Reading card	36.67%, 22	15.00%, 9
	Cover surrounding text	Reading frame	8.33%, 5	1.67%, 1
	Use aid to keep reading on a line	Reading ruler	10.00%, 6	-
Spoken alternatives				
	Use spoken books	Daisy player	30.00%, 18	13.33%, 8
	Use spoken subtitles	Go Box	23.33%, 14	3.33%, 2
	Use text to speech	E-reader/tablet/computer	5.00%, 3	-
	Use spoken alternative (e.g., news)	Radio	3.33%, 2	-
	Record memos instead of writing them down	Memo recorder	1.67%, 1	-

Glasses				
	Use better correction	New glasses	23.33% 14	-
	Do not use multifocal glasses	Separate reading glasses	15.00%, 9	10.00%, 6
	Use prism correction	Prism glasses	8.33%, 5	6.67%, 4
Covering one eye (e.g., to reduce double vision)				
	Cover one eye	Eye patch	20.00%, 12	10.00%, 6
	Partly cover one eye	Filter glasses	1.67%, 1	1.67%, 1
Sitting posture/text positioning				
	Optimize sitting posture/text position	Reading stand	18.33%, 11	5.00%, 3
	Optimize sitting posture	-	15.00%, 9	-
	Decrease reading distance	-	11.67%, 7	-
	Lay text down	-	3.33%, 2	-
	Optimize sitting posture/text position	Laptop stand	1.67%, 1	-
	Increase reading distance	-	1.67%, 1	-
	Hold text up	-	1.67%, 1	-
	Move text in time	-	1.67%, 1	-
Scheduling				
	Take more breaks	-	6.67%, 4	-
	Read at specific time of day	-	-	1.67%, 1
Others				
	Blink more often	-	8.33%, 5	-
	Read more slowly	-	1.67%, 1	-
	Put glasses in fixed spot	-	1.67%, 1	-
	Read with heavy object to reduce tremor	-	1.67%, 1	-

Note. Percentages do not end up to 100%; not everyone received all mentioned advice and aids

Discussion

Reading complaints are of high prevalence and have an impact on the quality of life in people with PD. Since little is known about reading complaints in PD, this study gives a detailed insight into reading complaints and shows which functional impairments may contribute to reading complaints in people with PD. Furthermore, this study demonstrates which advice and aids may be effective in alleviating reading complaints.

The first aim of the present study was to provide more insight into the reading complaints of people with PD. Different descriptions of reading complaints were reported. In accordance with previous studies, descriptions such as the perception of moving words and letters, blurred vision, diplopia, and visual discomfort during reading were found (Bargagli et al., 2020; Urwyler et al., 2014). However, also additional reading complaints were mentioned that have not been found in people with PD in previous literature, including having difficulty continuing reading on the same line, skipping words, and feeling fatigued/exerted during/after reading. One explanation for the additional descriptions of reading complaints in our study may be that in previous literature semi-structured questionnaires about reading complaints in people with PD were rarely used. Without semi-structured questioning, information of non-motor symptoms of people with PD might be overlooked (Chaudhuri et al., 2010). Using a semi-structured questionnaire ensures that our results better reflect the reading complaints experienced by people with PD and show which reading complaints may interfere with the participation in everyday life of people with PD. Preset response options occurred more frequently than spontaneous complaints, which may be because people with PD have more difficulty expressing their complaints when they are not directly asked about them, and therefore are more likely to choose preset responses when they are available (Chaudhuri et al., 2010). Therefore, it could be possible that the spontaneous complaints occur in higher frequency than currently reported. It is striking that the spontaneous description feeling

fatigued/exerted during/after reading was mentioned the third most often and was seen more frequently than one of the preset descriptions. The frequent occurrence of this complaint could be due to the fact that increased fatigue is one of the symptoms of PD (Stocchi et al., 2014). Furthermore, it could be explained by possible visual, visual perceptual and cognitive impairments that are common in people with PD (Bodis-Wollner, 2003). With impairments in these functions, the demanding task of reading becomes an even more fatiguing process. Other frequently mentioned reading complaints may be attributed to functional difficulties that accompany PD as well. Having difficulty to continue reading on the same line and skipping words while reading may be explained by e.g., impaired visual acuity or contrast sensitivity which can lead to not being able to see the line/words properly, or by impairments in visual attention, or verbal memory which may lead to not being able to remember what and where was read.

The second aim of this study was to create a more accurate account of visual, visual perceptual and cognitive impairments contributing to reading complaints in people with PD. RC+ showed poorer functioning and the largest difference compared to RC- in the visual functions contrast sensitivity, reading acuity and visual acuity and in the visual perceptual functions visual motor speed/mental flexibility and lateralized visual attention/spatial cognition. These differences were expected from previous findings, since all of these functions play a role in the process of reading (Archibald et al., 2011; Gavril, Roșan & Szamosközi, 2021; Kwan et al., 2022; Moes & Lombardi, 2009). Impaired visual acuity and reading acuity can lead to a less sharp image of a word projected from the lens onto the retina, which makes reading difficult. With impaired contrast sensitivity, it is a challenge to read phrases with less optimal contrast, like e.g., in a newspaper which is often read by the elderly population. Lateralized visual attention/spatial cognition plays a crucial role in reading skill development and is important for processing words and controlling eye movements during reading (Franceschini et

al., 2021; Gavril, Rosan & Szamosközi, 2021). Visual-motor speed/mental flexibility are often impaired in people with PD (Dujardin et al., 2013). Previous literature showed that these functions play a major role in reading and reading comprehension (Colé, Duncan & Blaye, 2014). Furthermore, the task of visual-motor speed/mental flexibility requires inhibitory control to supress irrelevant responses. It is known that people with PD have difficulty ignoring irrelevant words while reading, which might represent more impairments in RC+ compared to RC- in this task (Biundo et al., 2011; Marí-Beffa et al., 2005). In the functions visual acuity, reading acuity, visual motor speed/mental flexibility and lateralized visual attention/spatial cognition impairments in RC- were also found. This implies that these functions are not a full explanation for reading complaints in people with PD. However, large differences were found between RC+ and RC- in these functions, suggesting that impairments in these functions may still contribute most to reading complaints in people with PD. It may even be more likely that reading complaints are present when impairments of these functions occur in combination. In summary, it might be possible that impairments in visual acuity, reading acuity, contrast sensitivity, visual motor speed/mental flexibility and lateralized visual attention/spatial cognition are the most important contributors of reading complaints in people with PD.

Of the five mentioned functions with the largest differences between the groups, contrast sensitivity was the only function that showed impairments exclusively in RC+. The function contrast sensitivity plays a major role in reading (Chung et al., 2019). It determines how well a person can distinguish a letter from the background, especially in lower contrast situations. Our study showed that contrast sensitivity probably plays an even greater role in the process of reading in people with PD than other functions, such as visual acuity. That is, if contrast sensitivity is impaired, one might be more likely to experience reading complaints than if other functions are impaired. For this reason, special attention should be paid to this function in visual rehabilitation in people with PD and reading complaints.

Based on previous studies, larger differences were expected between RC+ and RC- in impaired eye movements, including smooth pursuit, stereopsis, saccades and convergence and in visual search, visual crowding and visual spatial memory (Franceschini et al., 2021; Gottlob et al., 2004; Huestegge et al., 2012; Jehangir et al., 2018; Yu et al., 2016). RC+ showed poorer functioning in all of these functions, but the differences between the two groups were small to negligible. This also applied to cognitive functions. Since cognitive functions play an important role in reading and symptoms of PD also include cognitive impairment, larger differences between the groups were expected, but were not found in the present study (Commodari & Guarnera, 2005; Savage, Lavers & Pillay, 2007; Watson & Leverenz, 2010). Nevertheless, RC+ showed poorer functioning than RC- in 28 of the 38 functions and impairments were found in RC+ in all 38 measured functions. Therefore, it cannot be said that these functions contribute to reading complaints, but this also cannot be ruled out. The diversity of impairments in visual, visual perceptual and cognitive functions that could lead to reading complaints in people with PD may be high.

An additional aim of the present study was to identify which advice and aids are provided in rehabilitation and are effective for people with PD in order to alleviate their reading complaints. Various advice and aids were attempted and mostly they were found to be effective. Effective advice and aids reduce the impact of impaired visual and visual perceptual functions. Many of the effective advice and aids mentioned are directed at visual impairments that also contributed most to reading complaints in our study. Wearing new glasses to improve visual acuity, or enlarging text by, for example, using a magnifying lamp, which reduces the impact of impaired visual acuity in the process of reading was shown to be effective. Using electronic aids/displays, including e-readers, tablets and computers, by formatting text and/or adjusting contrast was shown to be effective, which again targets visual acuity and contrast sensitivity. Furthermore, applying increased task lightning can help people with reduced contrast

sensitivity. Another effective aid was the use of reading cards to cover the text, which reduces visual distraction during reading and reduces the impact of impaired visual attention while reading. Taking breaks while reading was also shown to be effective, which could lead to feeling less fatigued/exerted during/after reading and thus target one of the most commonly mentioned reading complaints. No advice and aids were found that targeted cognitive impairment, which could possibly be because cognitive impairments seem to contribute less to reading complaints in people with PD than visual and visual perceptual impairments. Thus, the effective advice and aids are consistent with the results found in this study and are largely directed at visual and visual perceptual impairments, and at the mentioned reading complaints of people with PD.

Some advice and aids were perceived as ineffective, but did not worsen reading complaints. That some advice and aids were seen as ineffective may be explained by the target population. PD is a disease whose prevalence increases with age. In older age, not all people are familiar with the use of e.g., electronic devices, and learning to use them requires extra training. Use of aids may also be difficult for people with PD due to e.g., motor impairments or reduced cognition.

Clinical implications

The present study showed that some impaired visual (visual acuity, reading acuity and contrast sensitivity) and visual perceptual (visual motor speed/mental flexibility and lateralized visual attention/spatial cognition) functions contribute more to reading complaints in people with PD than other functional impairments. Likewise, advice and aids matching the most contributing impaired functions were perceived as effective. This means that these functions should receive the most attention in both assessment and rehabilitation. Thus, the duration of assessments and also rehabilitation could be significantly shortened, which could greatly benefit the target group since they would have to exert less physical and mental effort in

rehabilitation and assessment, but also reduce costs of rehabilitation. However, this study also reflects the diversity of reading complaints, impaired functions and effective advice and aids and it cannot be ruled out that functions for which smaller differences between the groups were found do contribute to reading complaints. It should therefore not be forgotten to always address the reading complaints of people with PD individually, in case the rehabilitation of the above-mentioned functions and complaints has not yet succeeded.

Strengths, limitations and recommendations for future research

The present study is the first study that has summarized reading complaints in people with PD using a semi-structured questionnaire, has assessed a large test battery of visual, visual perceptual, and cognitive functions that may contribute to reading complaints in people with PD, and presented effective advice and aids of reading complaints, thereby making an essential contribution to improved visual rehabilitation of people with PD and reading complaints.

However, there are some limitations to this study. First, the two compared groups, RC+ and RC-, were small. In particular, the RC- group was small because our study took place in visual rehabilitation and most people with PD and visual complaints experienced reading complaints. Further, taking such a large test battery in conjunction with the target group is difficult due to the increased age and symptoms of PD (e.g., motor impairments or cognitive difficulties). Because of small sample sizes, the generalizability of the results of the study is limited. This invokes recommendations for future research in which larger groups are used to increase the generalizability of the results found. However, since the results of our study come from the rehabilitation setting, the mentioned recommendations can be reliably applied in rehabilitation and assessment.

Age and H&Y stage did not differ significantly between the groups, but did show medium to large ES, respectively, for which this study did not correct. It was decided not to include age and H&Y stage in the analyses, because it could be possible that both variables

explain reading complaints to some extent. If it was corrected, information regarding reading complaints might be lost.

Lastly, as this study took place in visual rehabilitation, visual complaints were present in both groups. However, reading complaints were most likely the only difference between RC+ and RC-. In addition, it is difficult to correct for this by using a different comparison group, because someone with reading complaints is likely to experience other visual complaints as well. If a group without visual complaints was used as a comparison group, then the difference between the two groups would not only be explained by the reading complaint, but also by other visual complaints.

Conclusion

People with PD exhibit a wide range of reading complaints. The most common and prominent complaints are having difficulty continuing reading on the same line, skipping words while reading, and feeling fatigued during reading. Several functional impairments have been found to contribute to reading complaints in people with PD. The most important contributors are impairments of the visual functions contrast sensitivity, reading acuity and visual acuity and impairments of the visual perceptual functions visual motor speed/mental flexibility and lateralized visual attention/spatial cognition. Cognitive functions tend to be less associated with reading complaints. The effective advice and aids fit with the rest of the results and mostly tailored to visual impairments. When a person with PD presents with reading complaints, the functional impairments that contribute most to reading complaints in people with PD should be the first to be assessed. However, due to the diversity of reading complaints and functional impairments in both people with and without reading complaints, we cannot rule out the possibility that other functional impairments contribute to reading complaints. Therefore, rehabilitation should always be tailored to the individual.

References

Archibald, N. K., Clarke, M. P., Mosimann, U. P., & Burn, D. J. (2011). Visual symptoms in parkinson's disease and parkinson's disease dementia. *Movement Disorders: Official Journal of the Movement Disorder Society, 26*(13), 2387–95. https://doi.org/10.1002/mds.23891

Armstrong, R. A. (2015). Oculo-visual dysfunction in Parkinson's disease. *Journal of Parkinson's Disease, 5*(4), 715–26. https://doi.org/10.3233/JPD-150686

Bargagli, A., Fontanelli, E., Zanca, D., Castelli, I., Rosini, F., Maddii, S., Di Donato, I., Carluccio, A., Battisti, C., Tosi, G. M., Dotti, M. T., & Rufa, A. (2020). Neurophthalmologic and orthoptic ambulatory assessments reveal ocular and visual changes in patients with early alzheimer and parkinson's disease. *Frontiers in Neurology, 11*, 577362–577362. https://doi.org/10.3389/fneur.2020.577362

Biousse, V., Skibell, B. C., Watts, R. L., Loupe, D. N., Drews-Botsch, C., & Newman, N. J. (2004). Ophthalmologic features of parkinson's disease. *Neurology, 62*(2), 177–80.

Biundo, R., Formento-Dojot, P., Facchini, S., Vallelunga, A., Ghezzo, L., Foscolo, L., Meneghello, F., & Antonini, A. (2011). Brain volume changes in Parkinson's disease and their relationship with cognitive and behavioural abnormalities. *Journal of the neurological sciences, 310*(1-2), 64-69. https://doi.org/10.1016/j.jns.2011.08.001

Bodis-Wollner, I. (2003). Neuropsychological and perceptual defects in parkinson's disease. *Parkinsonism and Related Disorders: Supplement 2, 9*, 83–89. https://doi.org/10.1016/S1353-8020(03)00022-1

Boone, K. B., Lu, P., & Herzberg, D. (2002). The Dot Counting Test manual. Los Angeles, CA: Western Psychological Services.

Bucci, M. P. (2021). Visual training could be useful for improving reading capabilities in dyslexia. *Applied Neuropsychology: Child, 10*(3), 199–208. https://doi.org/10.1080/21622965.2019.1646649

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: a meta-analysis. *Learning and Individual Differences, 19*(2), 246–251. https://doi.org/10.1016/j.lindif.2008.10.002

Chaudhuri, K. R., Prieto-Jurcynska, C., Naidu, Y., Mitra, T., Frades-Payo, B., Tluk, S., Ruessmann, A., Odin, P., Macphee, G., Stocchi, F., Ondo, W., Sethi, K., Schapira, A. H. V., Castrillo, J. C. M., & Martinez-Martin, P. (2010). The nondeclaration of nonmotor symptoms of Parkinson's disease to health care professionals: an international study using the nonmotor symptoms questionnaire. *Movement Disorders, 25*(6), 704–709. https://doi.org/10.1002/mds.22868

Chung, S. T. L. (2020). Reading in the presence of macular disease: a mini-review. *Ophthalmic & Physiological Optics: The Journal of the British College of Ophthalmic Opticians (Optometrists), 40*(2), 171–186. https://doi.org/10.1111/opo.12664

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

Colé, P., Duncan, L. G., & Blaye, A. (2014). Cognitive flexibility predicts early reading skills. *Frontiers in Psychology, 5*, 565. https://doi.org/10.3389/fpsyg.2014.00565

Commodari, E., & Guarnera, M. (2005). Attention and reading skills. *Perceptual and Motor Skills, 100*(2), 375–386. https://doi.org/10.2466/pms.100.2.375-386

Crucian, G. P., Armaghani, S., Armaghani, A., Foster, P. S., Burks, D. W., Skoblar, B., Drago, V., & Heilman, K. M. (2010). Visual-spatial disembedding in parkinson's disease.

Journal of Clinical and Experimental Neuropsychology, 32(2), 190–200. https://doi.org/10.1080/13803390902902441

Dujardin, K., Tard, C., Duhamel, A., Delval, A., Moreau, C., Devos, D., & Defebvre, L. (2013). The pattern of attentional deficits in parkinson's disease. *Parkinsonism and Related Disorders, 19*(3), 300–305. https://doi.org/10.1016/j.parkreldis.2012.11.001

Ekker, M. S., Janssen, S., Seppi, K., Poewe, W., de Vries, N. M., Theelen, T., Nonnekes, J., & Bloem, B. R. (2017). Ocular and visual disorders in Parkinson's disease: common but frequently overlooked. *Parkinsonism & Related Disorders, 40*, 1–10. https://doi.org/10.1016/j.parkreldis.2017.02.014

Elwan, F., Gaballah, S., & Khalifa, A. G. (2019). Impairment of some cognitive process in children with reading disability in middle childhood, late childhood, and early adolescence. *Middle East Current Psychiatry, 26*(1), 1–6. https://doi.org/10.1186/s43045-019-0001-z

Esterman, B. (1982). Functional scoring of the binocular field. *Ophthalmology, 89*(11), 1226–1234. https://doi.org/10.1016/s0161-6420(82)34647-3

Farnsworth, D. (1957). The Farnsworth–Munsell 100-Hue test for the examination of color vision. Baltimore, MD: Munsell Color Company.

Ferris, F. L., Kassoff, A., Bresnick, G. H., & Bailey, I. (1982). New visual acuity charts for clinical research. *American Journal of Ophthalmology, 94*(1), 91–96. https://doi.org/10.1016/0002-9394(82)90197-0

Franceschini, S., Bertoni, S., Puccio, G., Mancarella, M., Gori, S., & Facoetti, A. (2021). Local perception impairs the lexical reading route. *Psychological Research, 85*(4), 1748–1756. https://doi.org/10.1007/s00426-020-01326-z

Gauthier, L., Dehaut, F., & Joanette, Y. (1989). The bells test: a quantitative and qualitative test for visual neglect. *International journal of clinical neuropsychology, 11*(2), 49-54.

Gavril, L., Roșan, A., & Szamosközi, Ș. (2021). The role of visual-spatial attention in reading development: a meta-analysis. Cognitive Neuropsychology, 38(6), 387–407. https://doi.org/10.1080/02643294.2022.2043839

Georgiou, G. K., & Das, J. P. (2016). What component of executive functions contributes to normal and impaired reading comprehension in young adults? *Research in Developmental Disabilities, 49-50*, 118–28. https://doi.org/10.1016/j.ridd.2015.12.001

Ghaferi, A. A., Schwartz, T. A., & Pawlik, T. M. (2021). STROBE reporting guidelines for observational studies. *JAMA surgery, 156*(6), 577-578.

Ginsburg, A.P. (1984). A new contrast sensitivity vision test chart. *Optometry and Vision Science, 61*(6), 403–407. https://doi.org/10.1097/00006324-198406000-00011

Gori, S., & Facoetti, A. (2015). How the visual aspects can be crucial in reading acquisition: the intriguing case of crowding and developmental dyslexia. *Journal of Vision, 15*(1), 15–8. https://doi.org/10.1167/15.1.8

Gottlob, I., Proudlock, F. A., Shekhar, H., & Rajabally, Y. (2004). Reading in Parkinson's disease. *Investigative Ophthalmology & Visual Science, 45*(13), 2517-2517.

Griffing, H., & Franz, S. I. (1896). On the conditions of fatigue in reading. *Psychological Review, 3*(5), 513–530. https://doi.org/10.1037/h0075858

Hedges, L. V., & Olkin, I. (2014). *Statistical methods for meta-analysis*. Academic press.

Hoehn, M. M., & Yahr, M. D. (1998). Parkinsonism: onset, progression, and mortality. *Neurology, 50*(2), 318–318. https://doi.org/10.1212/WNL.50.2.318

Huestegge, L., Heim, S., Zettelmeyer, E., & Lange-Kttner, C. (2012). Gender-specific contribution of a visual cognition network to reading abilities. *British Journal of Psychology, 103*(1), 117–128.

Huizinga, F., Heutink, J., de Haan, G., van der Lijn, I., van der Feen, F., Vrijling, A., Melis-Dankers, B., de Vries, S., Tucha, O., & Koerts, J. (2020). The development of the

screening of visual complaints questionnaire for patients with neurodegenerative disorders: evaluation of psychometric features in a community sample. *Plos-One, 15*(4). https://doi.org/10.1371/journal.pone.0232232

IBM Corp. (2022). IBM SPSS Statistics for Macintosh, Version 29.0. Armonk, NY: IBM Corp [Computer software]

Jehangir, N., Yu, C. Y., Song, J., Shariati, M. A., Binder, S., Beyer, J., Santini, V., Poston, K., & Liao, Y. J. (2018). Slower saccadic reading in parkinson's disease. *Plos One, 13*(1), 0191005. https://doi.org/10.1371/journal.pone.0191005

Joo, S. J., White, A. L., Strodtman, D. J., & Yeatman, J. D. (2018). Optimizing text for an individual's visual system: The contribution of visual crowding to reading difficulties. *Cortex, 103*, 291-301.

Kerkhoff, G., Schaub, J., & Zihl, J. (1990). Die Anamnese zerebral bedingter Sehstörungen. *Nervenarzt, 61*(12), 711-718.

Kessels, R. P. C., Van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & De Haan, E. H. F. (2000). The Corsi Block-Tapping Task: Standardization and normative data. *Applied Neuropsychology, 7*, 252–258. doi:10.1207=S15324826AN0704_8

Kim, H.-Y. (2017). Statistical notes for clinical researchers: chi-squared test and fisher's exact test. *Restorative Dentistry & Endodontics, 42*(2), 152–155. https://doi.org/10.5395/rde.2017.42.2.152

Kooijman A. C., & Beerthuizen J.J.G. (1996). The new reading charts, M-unit. *Vision '96: Proceedings of the International Low Vision Conference, 1*, 39-44. ONCE: Madrid.

Kooijman, A. C., Stellingwerf, N., Cornelissen, F. W., & Van der Wildt, G. J. (1993). Groningen edge contrast chart design and glare measurements. *International Ophthalmology, 17*(5), 28–28.

Kwan, S. C. K., Atiya, A., Hussaindeen, J. R., Praveen, S., & Ambika, S. (2022). Ocular features of patients with parkinson's disease examined at a neuro-optometry clinic in a tertiary eye care center. *Indian Journal of Ophthalmology, 70*(3), 958–961. https://doi.org/10.4103/ijo.IJO_948_21

Kwon, M., Legge, G. E., & Dubbels, B. R. (2007). Developmental changes in the visual span for reading. *Vision research, 47*(22), 2889-2900.

Lanthony, P. (1978). The desaturated panel D-15. *Documenta Ophthalmologica, 46*(1), 185-189.

Van der Lijn, I., de Haan, G. A., Huizinga, F., van der Feen, F. E., Rutgers, A. W. F., Stellingwerf, C., van Laar, T., & Heutink, J. (2022). Self-reported visual complaints in people with parkinson's disease: a systematic review. Journal of Parkinson's Disease, 12(3), 785–806. https://doi.org/10.3233/JPD-202324

Van der Lijn, I., de Haan, G. A., van der Feen, F. E., Huizinga, F., Stellingwerf, C., van Laar, T., & Heutink, J. (in press). Prevalence and nature of self-reported visual complaints in people with Parkinson’s disease - Use of the Screening Visual Complaints questionnaire.

Marí-Beffa Paloma, Hayes, A. E., Machado, L., & Hindle, J. V. (2005). Lack of inhibition in parkinson's disease: evidence from a lexical decision task. *Neuropsychologia, 43*(4), 638–646. https://doi.org/10.1016/j.neuropsychologia.2004.07.006

Markowitz, M., Daibert-Nido, M., & Markowitz, S. N. (2018). Rehabilitation of reading skills in patients with age-related macular degeneration. Canadian Journal of Ophthalmology. *Journal Canadien D'ophtalmologie, 53*(1), 3–8. https://doi.org/10.1016/j.jcjo.2017.10.042

Meireles, J., & Massano, J. (2012). Cognitive impairment and dementia in parkinson's disease: clinical features, diagnosis, and management. *Frontiers in Neurology, 3*, 88–88. https://doi.org/10.3389/fneur.2012.00088

Meng, X., Zeng, B., Zhou, X., Cheng-Lai, A., & Stein, J. F. (2011). Dynamic visual perception and reading development in chinese school children. *Annals of Dyslexia, 61*(2), 161–176. https://doi.org/10.1007/s11881-010-0049-2

Moes, E., & Lombardi, K. M. (2009). The relationship between contrast sensitivity, gait, and reading speed in parkinson's disease. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 16*(2), 121–32. https://doi.org/10.1080/13825580802233418

Murray, L. L., & Rutledge, S. (2014). Reading comprehension in parkinson's disease. *American Journal of Speech-Language Pathology, 23*(2), 246–58. https://doi.org/10.1044/2014_AJSLP-13-0087

Neumann, G., Schaadt, A.-K., Reinhart, S., & Kerkhoff, G. (2016). Clinical and psychometric evaluations of the cerebral vision screening questionnaire in 461 nonaphasic individuals poststroke. *Neurorehabilitation and Neural Repair, 30*(3), 187–198. https://doi.org/10.1177/1545968315585355

Nieuwe kijk op het ontstaan van de ziekte van Parkinson. (2019, 25 juni). Amsterdam UMC, Locatie VUmc. Retrieved March 1, 2022, from https://www.vumc.nl/nieuws/nieuwsdetail/nieuwe-kijk-op-het-ontstaan-van-de-ziekte-van-parkinson.htm

Owsley, C. (2016). Vision and aging. *Annual Review of Vision Science, 2*(1), 255–271. https://doi.org/10.1146/annurev-vision-111815-114550

Parkinson, J. (2002). An essay on the shaking palsy. *The Journal of Neuropsychiatry and Clinical Neurosciences, 14*(2), 223–236. https://doi.org/10.1176/jnp.14.2.223

Pelli, D. G., Tillman, K. A., Freeman, J., Su, M., Berger, T. D., & Majaj, N. J. (2007). Crowding and eccentricity determine reading rate. *Journal of Vision, 7*(2), 1–36. https://doi.org/10.1167/7.2.20

Pieri, V., Diederich, N. J., Raman, R., & Goetz, C. G. (2000). Decreased color discrimination and contrast sensitivity in Parkinson's disease. *Journal of the Neurological Sciences, 172*(1), 7–11.

Raasch, T. W., & Rubin, G. S. (1993). Reading with low vision. *Journal of the American Optometric Association.*

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372–422.

Rayner, K. (2009). Eye movements and attention in reading, scene perception, and visual search. *Quarterly Journal of Experimental Psychology -New Series-, 62*(8), 1457–1506.

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and motor skills, 8*(3), 271-276.

Rolinski, M., Zokaei, N., Baig, F., Giehl, K., Quinnell, T., Zaiwalla, Z., Mackay, C. E., Husain, M., & Hu, M. T. M. (2016). Visual short-term memory deficits in rem sleep behaviour disorder mirror those in parkinson's disease. *Brain, 139*(1), 47–53. https://doi.org/10.1093/brain/awv334

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

Sato, E., Onitsuka, T., Ninomiya, H., Nakamura, I., & Kanba, S. (2014). Prism adaptation and perceptual skill learning deficits in early-stage parkinson's disease. *Neuropsychobiology, 165-172*, 165–172. https://doi.org/10.1159/000365485

Savage, R., Lavers, N., & Pillay, V. (2007). Working memory and reading difficulties: What we know and what we don't know about the relationship. *Educational psychology review, 19*(2), 185-221. https://doi.org/10.1007/s10648-006-9024-1

Savitt, J., & Mathews, M. (2018). Treatment of visual disorders in parkinson disease. *Current Treatment Options in Neurology, 20*(8), 1–15. https://doi.org/10.1007/s11940-018-0519-0

Schmand, B., Groenink, S. C., & Van den Dungen, M. (2008). Letter fluency: psychometric properties and Dutch normative data. *Tijdschrift voor gerontologie en geriatrie, 39*(2), 64-76. https://doi.org/10.1007/bf03078128

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3–4), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Spinhoven, P. H., Ormel, J., Sloekers, P. P. A., Kempen, G. I. J. M., Speckens, A. E., & van Hemert, A. M. (1997). A validation study of the Hospital Anxiety and Depression Scale (HADS) in different groups of Dutch subjects. *Psychological medicine, 27*(2), 363-370. https://doi.org/10.1017/S0033291796004382

Stocchi, F., Abbruzzese, G., Ceravolo, R., Cortelli, P., D'Amelio, M., De Pandis, M. F., Fabbrini, G., Pacchetti, C., Pezzoli, G., Tessitore, A., Canesi, M., Iannacone, C., Zappia, M., & For, the F. O. R. T. E. S. G. (2014). Prevalence of fatigue in parkinson disease and its clinical correlates. *Neurology, 83*(3), 215–220. https://doi.org/10.1212/WNL.0000000000000587

Stock, L., Krüger-Zechlin, C., Deeb, Z., Timmermann, L., & Waldthaler, J. (2020). Natural reading in parkinson's disease with and without mild cognitive impairment. *Frontiers in Aging Neuroscience, 12*, 120–120. https://doi.org/10.3389/fnagi.2020.00120

Taylor, L. B. (1969). Localisation of Cerebral Lesions by Psychological Testing. *Neurosurgery, 16*, 269-287. doi: 10.1093/neurosurgery/16.cn_suppl_1.269.

Tomlinson, C. L., Stowe, R., Patel, S., Rick, C., Gray, R., & Clarke, C. E. (2010). Systematic review of levodopa dose equivalency reporting in Parkinson's disease. *Movement disorders, 25*(15), 2649-2653.

Torfs, K., Vancleef, K., Lafosse, C., Wagemans, J., & de-Wit, L. (2014). The Leuven Perceptual Organization Screening Test (L-POST), an online test to assess mid-level visual perception. *Behavior Research Methods, 46*(2), 472-487.

Underwood, G., Hubbard, A., & Wilkinson, H. (1990). Eye fixations predict reading comprehension: the relationships between reading skill, reading speed, and visual inspection. *Language and Speech, 33*(1), 69–81. https://doi.org/10.1177/002383099003300105

UNESCO Institute for Statistics. (2012). International standard classification of education: ISCED 2011. Comparative Social Research, 30.

Urwyler, P., Nef, T., Killen, A., Collerton, D., Thomas, A., Burn, D., McKeith, I., & Mosimann, U. P. (2014). Visual complaints and visual hallucinations in parkinson's disease. *Parkinsonism & Related Disorders, 20*(3), 318–22. https://doi.org/10.1016/j.parkreldis.2013.12.009

de Vries, S. M., Heutink, J., Melis-Dankers, B. J. M., Vrijling, A. C. L., Cornelissen, F. W., & Tucha, O. (2018). Screening of visual perceptual disorders following acquired brain injury: A Delphi study. *Applied neuropsychology. Adult, 25*(3), 197–209. https://doi.org/10.1080/23279095.2016.1275636

de Vries, S. M., Tucha, O., Melis-Dankers, B. J. M., Vrijling, A. C. L., Ribbers, S., Cornelissen, F. W., & Heutink, J. (2022). The birthday party test (bpt): a new picture description test to support the assessment of simultanagnosia in patients with acquired brain injury. *Applied Neuropsychology: Adult, 29*(3), 383–396. https://doi.org/10.1080/23279095.2020.1763998

Warrington, E. K., & James, M. (1991). The Visual Object and Space Perception Battery, Thames Valley Test Company, Bury St. Edmunds, UK.

Watson, G. S., & Leverenz, J. B. (2010). Profile of cognitive impairment in parkinson's disease. *Brain Pathology, 20*(3), 640–645. https://doi.org/10.1111/j.1750-3639.2010.00373.x

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale (4th ed.)*. San Antonio, TX: Pearson Assessment.

Whittaker, S. G., & Lovie-Kitchin, J. (1993). Visual requirements for reading. *Optometry and Vision Science: Official Publication of the American Academy of Optometry, 70*(1), 54–65.

Van Wingerden, E., Segers, E., van Balkom, H., & Verhoeven, L. (2018). Cognitive constraints on the simple view of reading: a longitudinal study in children with intellectual disabilities. *Scientific Studies of Reading, 22*(4), 321–334.

Yari, N., Almarzouqi, S.J., Morgan, M.L., Lee, A.G. (2018). Swinging-Light Test, for RAPD Identification. In: Schmidt-Erfurth, U., Kohnen, T. (eds) Encyclopedia of Ophthalmology. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-69000-9_1227

Yeatman, J. D., & White, A. L. (2021). Reading: the confluence of vision and language. *Annual Review of Vision Science, 7*(1), 487–517. https://doi.org/10.1146/annurev-vision-093019-113509

Yu, C. Y., Lee, T., Shariati, M. A., Santini, V., Poston, K., & Liao, Y. J. (2016). Abnormal eye movement behavior during reading in parkinson's disease. *Parkinsonism & Related Disorders, 32*, 130–132. https://doi.org/10.1016/j.parkreldis.2016.08.008

Zhu, Z., Hu, Y., Liao, C., Huang, R., Keel, S., Liu, Y., & He, M. (2019). Perceptual learning of visual span improves chinese reading speed. *Investigative Opthalmology & Visual Science, 60*(6), 2357–2357. https://doi.org/10.1167/iovs.18-25780

Zokaei, N., McNeill, A., Proukakis, C., Beavan, M., Jarman, P., Korlipara, P., Hughes, D., Mehta, A., Hu, M. T. M., Schapira, A. H. V., & Husain, M. (2014). Visual short-term memory deficits associated with gba mutation and parkinson's disease. *Brain, 137*(8), 2303–2311. https://doi.org/10.1093/brain/awu143

Appendix A

Cerebral Visual Complaints questionnaire (CVCq)

Cerebrale Visuele Stoornissen (CVS)

Deze vragenlijst wordt afgenomen bij elke cliënt met niet-aangeboren hersenletsel.

Cliëntnummer: ----------

Datum afname: ----------

Naam intaker: ----------

Dit is een gestandaardiseerde vragenlijst voor visuele klachten bij mensen met niet-aangeboren hersenletsel.

Stel de vragen uit deze lijst door ze rustig en duidelijk voor te lezen. Wanneer een vraag ook bij herhaling niet duidelijk is, kan de vraag anders geformuleerd worden. Het is echter niet de bedoeling alle vragen zelf te formuleren.

Enkele vragen zijn specifiek bedoeld voor mensen met multiple sclerose (MS) of de ziekte van Parkinson. Deze vragen zijn gemarkeerd met een * en kunnen worden over geslagen wanneer een cliënt geen MS of ziekte van Parkinson heeft. De overige vragen worden aan iedere cliënt met niet-aangeboren hersenletsel gesteld.

Instructie (letterlijk voorlezen)

"Dit is een vragenlijst met uitspraken over problemen die met uw gezichtsvermogen te maken hebben, of over gevoelens die u over uw gezichtsvermogen heeft.

Als u een bril of contactlenzen heeft, ga er dan bij de beantwoording van de vragen vanuit dat u deze draagt.

Ik lees steeds een vraag voor. Elke vraag heeft meerdere antwoordmogelijkheden. Kies het antwoord dat het meest op u van toepassing is. Het gaat daarbij steeds om de ***afgelopen weken****.*

Als u niet zeker weet welk antwoord u moet kiezen, geef dan het best passende antwoord."

Algemeen

***1.** Heeft u sinds uw laatste bezoek aan de neuroloog een oogzenuwontsteking, een schub of een andere terugval gehad?

❒ nee
❒ ja, namelijk ----------

2. Ervaart u in het dagelijks leven problemen met uw zicht/het zien?

❒ nee → **ga naar vraag 3**
❒ ja → **vul tabel in (vraag 2.1 & 2.2)**

Informatie voor de intaker: let op! het gaat hier om spontaan gerapporteerde klachten van de cliënt

2.1. Kunt u aangeven welke problemen of klachten u ervaart met uw zicht/het zien?	**2.2.** Zijn deze klachten nauwelijks, soms of vaak/altijd aanwezig?
1	❒ nauwelijks ❒ soms ❒ vaak/altijd
2	❒ nauwelijks ❒ soms ❒ vaak/altijd
3	❒ nauwelijks ❒ soms ❒ vaak/altijd
4	❒ nauwelijks ❒ soms ❒ vaak/altijd
5	❒ nauwelijks ❒ soms ❒ vaak/altijd

"Ik ga u nu een aantal vragen stellen over het zien in het algemeen"

3. Heeft u de indruk dat u minder scherp bent gaan zien?

❒ nee/nauwelijks → **ga naar vraag 4**
❒ soms
❒ vaak/altijd →

***3.1.** Heeft u het idee dat u met beide ogen even scherp ziet?

❒ nee
❒ ja

3.2. Hoe zou u uw zicht/het zien beschrijven?

❒ zoals door bevuilde brilglazen
❒ zoals door een mist of nevel
❒ zoals door bevroren ramen of melkglas

❒ wazig, onscherp
❒ alsof u teveel alcohol heeft gedronken
❒ anders, namelijk _____

3.3. Wanneer heeft u hier last van? *(meerdere antwoorden mogelijk)*

❒ bij warmte
❒ bij vermoeidheid
❒ na inspanning:
  ❒ na lichamelijke inspanning
  ❒ na mentale inspanning (bijv. na een gesprek met meerdere personen, lezen, TV kijken, computergebruik)
❒ onder alle omstandigheden
❒ anders, namelijk _____

4. Heeft u last van dubbelzien of dubbelbeelden?

❒ nee/nauwelijks → **ga naar vraag 5**
❒ soms
❒ vaak/altijd

4.1. Verdwijnen dubbelbeelden als u één oog sluit?

❒ nee
❒ ja
❒ weet ik niet

5. Heeft u moeite met dieptezien of afstanden inschatten? *Informatie voor de intaker*: wanneer de vraag na herhaling niet begrepen wordt, dan 'nee/nauwelijks' invullen.

❒ nee/nauwelijks
❒ soms
❒ vaak/altijd

***6.** Heeft u last van trillende, schokkerige of bewegende beelden?

❒ nee/nauwelijks
❒ soms
❒ vaak/altijd

"Ik ga u nu een aantal vragen stellen over mobiliteit."

7. Heeft u, <u>vanwege uw zicht</u>, moeite met mobiliteit (denk aan botsen, struikelen, traplopen, vervoer of de weg vinden tijdens bijv. het lopen of fietsen)?

❒ nee, ik heb geen moeite met mobiliteit → **ga naar vraag 14**
❒ nee, ik verplaats mij niet zelfstandig → **ga naar vraag 14**
❒ ja

8. Heeft u, vanwege uw zicht, problemen met het ontwijken van mensen of voorwerpen of botst u soms tegen mensen of voorwerpen aan?

❒ nee/nauwelijks → **ga naar vraag 9**
❒ soms
❒ vaak/altijd

8.1. Aan welke kant botst u het meest of het vaakst (bijv. links/rechts/boven/onder)

---

9. Heeft u, vanwege uw zicht, moeite met traplopen?

❒ nee
❒ ja, naar boven
❒ ja, naar beneden
❒ ja, naar boven en naar beneden
❒ ik loop geen trap meer vanwege een andere reden

10. Met welke vormen van vervoer heeft u problemen vanwege uw zicht? *(meerdere antwoorden mogelijk)*

❒ lopen
❒ fietsen
❒ autorijden
❒ openbaar vervoer
❒ anders, namelijk ---

11. Vindt u het, vanwege uw zicht, moeilijk om in en rond uw eigen huis de weg te vinden?

❒ nee/nauwelijks
❒ soms
❒ vaak/altijd

12. Hoe vaak heeft u problemen met het oversteken van de straat vanwege uw zicht?

❒ nooit/nauwelijks
❒ soms
❒ vaak/altijd

13. Ervaart u nog meer problemen met betrekking tot mobiliteit vanwege uw zicht anders dan zojuist is gevraagd?

❒ nee
❒ ja, namelijk ---

"Ik ga u nu aan aantal vragen stellen over het zoeken en vinden van voorwerpen."

14. Heeft u, vanwege uw zicht, moeite met het zoeken en vinden van dingen?

❒ nee/nauwelijks → **ga naar vraag 15**
❒ soms
❒ vaak/altijd

14.1. Welke problemen ervaart u met betrekking tot het zoeken en vinden van dingen vanwege uw zicht? *(meerdere antwoorden mogelijk)*

❒ Het vinden van voorwerpen die op een tafel of bureau liggen waarop ook nog andere voorwerpen liggen
❒ Het vinden van voorwerpen die zich in een kamer bevinden
❒ Het vinden van boodschappen in een supermarkt
❒ Anders, namelijk _____

"Ik ga u nu een aantal vragen stellen over lezen. Ga er bij de beantwoording vanuit dat u uw leesbril of lenzen draagt, als u deze heeft."

15. Heeft u, vanwege uw zicht, moeite met lezen?

❒ nee/nauwelijks → **ga naar vraag 17**
❒ soms
❒ vaak/altijd

16. Welke van de volgende problemen met betrekking tot lezen ervaart u vanwege uw zicht? *(meerdere antwoorden mogelijk)*

❒ Letters gaan dansen
❒ Het overslaan van woorden of delen van zinnen aan de linker- of rechterkant van het blad
❒ Het vinden van het begin van de regel
❒ Op dezelfde regel blijven lezen
❒ Anders, namelijk _____

17. Heeft u moeite met het goed kunnen zien van letters in een tekst ten opzichte van de achtergrond?

❒ nee/nauwelijks
❒ soms
❒ vaak/altijd →

"De vragen die ik nu ga stellen gaan over licht en lichthinder."

18. Wordt u, meer dan vroeger, verblind door fel licht?

- ❒ nee/nauwelijks → **ga naar vraag 19**
- ❒ soms
- ❒ vaak/altijd →

18.1. Bij welke taken wordt u nu, meer dan vroeger, verblind door fel licht?
(meerdere antwoorden mogelijk)

- ❒ lezen
- ❒ lopen
- ❒ fietsen
- ❒ autorijden
- ❒ huishoudelijke taken
- ❒ anders, namelijk _____

18.2. In welke situaties ervaart u problemen met het zien ten gevolge van teveel licht?
(meerdere antwoorden mogelijk)

- ❒ binnenshuis
  - ❒ bij sfeerverlichting (woonkamer, restaurant)
  - ❒ bij kunstlicht (TL-verlichting, bijvoorbeeld werkplek)
  - ❒ bij een door daglicht goed verlichte kamer
- ❒ buitenshuis
  - ❒ op een zonnige dag
  - ❒ op een bewolkte dag

19. Heeft u de indruk dat alles donkerder lijkt (ervaart u een donkere waas) dan vroeger?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd →

20. Heeft u meer behoefte aan licht bij het zien dan vroeger?

- ❒ nee/nauwelijks → **ga naar vraag 21**
- ❒ soms
- ❒ vaak/altijd →

20.1. Bij welke taken heeft u nu, meer dan vroeger, behoefte aan meer licht?
(meerdere antwoorden mogelijk)

- ❒ lezen
- ❒ lopen
- ❒ fietsen
- ❒ autorijden
- ❒ huishoudelijke taken
- ❒ anders, namelijk _____

20.2. In welke situaties ervaart u problemen met het zien, omdat het te donker is?
(meerdere antwoorden mogelijk)

- ❒ binnenshuis
  - ❒ bij sfeerverlichting (woonkamer, restaurant)
  - ❒ bij kunstlicht (TL-verlichting, bijvoorbeeld werkplek)
  - ❒ bij een door daglicht goed verlichte kamer
- ❒ buitenshuis
  - ❒ op een bewolkte dag
  - ❒ bij schemering
  - ❒ 's nachts bij volle maan
- ❒ 's nachts zonder maanlicht

"De vragen die ik nu ga stellen gaan over overgangen van een lichte naar een donkere omgeving en van een donkere naar een lichte omgeving."

21. Heeft u moeite met het wennen aan licht of donker?

- ❒ nee → **ga naar vraag 24**
- ❒ ja

22. Als u het felle zonlicht in gaat, duurt het dan langer dan vroeger voordat u gewend bent aan het felle licht?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd →

23. Als u vanuit het felle zonlicht weer naar binnen gaat, duurt het dan langer dan vroeger voordat u gewend bent?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd →

Overig

24. Heeft u moeite met het herkennen van gezichten?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd

24.1. Heeft u moeite met het herkennen van gezichtsuitdrukkingen / emoties?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd

25. Ervaart u kleuren anders dan vroeger?

- ❒ n.v.t. → **ga naar vraag 25.2**
- ❒ nee/nauwelijks → **ga naar vraag 25.2**
- ❒ soms
- ❒ vaak/altijd →

25.1. Zijn de kleuren nu:

- ❒ meer mat en dof
- ❒ helderder
- ❒ ongewoon of vreemd
- ❒ anders, namelijk ----------

* **25.2.** Ervaart u kleuren in beide ogen gelijk?

- ❒ nee
- ❒ ja
- ❒ weet ik niet

26. Heeft u wel eens visuele gewaarwordingen zoals lichtflitsen, lijnen, sterren, gekleurde patronen, mist, of personen, dieren of voorwerpen?

- ❒ nee/nauwelijks → **ga naar vraag 27**
- ❒ soms
- ❒ vaak/altijd

26.1. Om wat voor soort gewaarwordingen gaat het? ----------

26.2. Weet u op het moment van de gewaarwording goed onderscheid te maken tussen de werkelijkheid en de gewaarwordingen?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd

26.3. Ervaart u de gewaarwordingen als beangstigend?

- ❒ nee/nauwelijks
- ❒ soms
- ❒ vaak/altijd

"We zijn bijna aan het einde gekomen van de vragenlijst."

27. Ervaart u nog andere problemen of klachten met uw zicht, anders dan zojuist genoemd?

- ❒ nee
- ❒ ja, namelijk ----------

"Dank u wel. Dit is het einde van de vragenlijst."

In te vullen door de intaker:
Overzichtelijke samenvatting van de klachten:

❒ Veranderingen in het gezichtsvermogen (zoals onscherp of dubbel zien)
❒ Mobiliteit
❒ Zoeken en vinden van voorwerpen
❒ Lezen
❒ Lichtbehoefte
❒ Lichthinder
❒ Overgangen van licht naar donker en andersom
❒ Het herkennen van gezichten en uitdrukkingen
❒ Het zien van kleuren
❒ Visuele gewaarwordingen
❒ Overige, namelijk ……
……

categorie “Wazig zien” (max=1) → ----

categorie “Contrastwaarneming” (max=1) → ----

categorie “Lichthinder” (max=1) → ----

categorie “Donkere Waas” (max=1) → ----

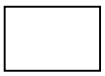
categorie “Verhoogde lichtbehoefte” (max=1) → ----

categorie “Verstoorde lichtadaptatie” (max=1) → ----

categorie “Verstoorde donkeradaptatie” (max=1) → ----

categorie “Kleuren” (max=1) → ----

Totaal aantal nonspecifieke visuele klachten (max= 8)



Bij aanwezigheid van **twee of meer** nonspecifieke visuele klachten, wordt het **VBO DiaNAH + Lichtlab onderzoek + VFO DiaNAH (adaptatieonderzoek) + kort NPO** geadviseerd.

Wanneer er **minder dan twee** nonspecifieke visuele klachten aanwezig zijn, wordt het **reguliere VBO + kort NPO** geadviseerd.

Appendix B

STROBE checklist

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-8; 9-10
Objectives	3	State specific objectives, including any prespecified hypotheses	8-9;10
Methods			
Study design	4	Present key elements of study design early in the paper	10; 16
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	10-11
Participants	6	*(a) Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	10-11
		(*b*) *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	10-14
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	11-14
Bias	9	Describe any efforts to address potential sources of bias	15
Study size	10	Explain how the study size was arrived at	10

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	16; 17
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	14-17
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	14
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	- - -
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10; 19; 25
		(b) Give reasons for non-participation at each stage	17; 19; 25
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	17-19
		(b) Indicate number of participants with missing data for each variable of interest	19-20; 25-26; 59 (Appendix C)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	-
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	-
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	-
		Cross-sectional study—Report numbers of outcome events or summary measures	19; 20-21; 25
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	22-24
		(*b*) Report category boundaries when continuous variables were categorized	-
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-

Continued on next page

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	18
Discussion			
Key results	18	Summarise key results with reference to study objectives	28-32
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	33-34
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	28-32; 34
Generalisability	21	Discuss the generalisability (external validity) of the study results	33
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	-

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Appendix C

Missing data from visual, visual perceptual and cognitive function tests

Missing data from visual, visual perceptual and cognitive function tests

	RC+		RC-		Total	
	N	%	N	%	N	%
Visual functions						
Visual acuity	0	0.00%	1	5.26%	1	1.35%
Contrast sensitivity	4	7.27%	3	15.79%	7	9.46%
Reading acuity	0	0.00%	2	10.53%	2	2.70%
Visual field	25	45.45%	6	31.58%	31	41.89%
Color vision	33	60.00%	9	47.37%	42	56.76%
Stereopsis	7	12.73%	2	10.53%	9	12.16%
Pupillary light reflex	17	30.91%	4	21.05%	21	28.38%
Eye alignment	3	5.45%	1	5.26%	4	5.41%
Eye motility	3	5.45%	1	5.26%	4	5.41%
Saccades	5	9.09%	3	15.79%	8	10.81%
Smooth pursuit	7	12.73%	2	10.53%	9	12.16%
Convergence	1	1.82%	1	5.26%	2	2.70%
Nystagmus	10	18.18%	4	21.05%	14	18.92%
Blink rate	16	29.09%	5	26.32%	21	28.38%
Optokinetic nystagmus	14	25.45%	6	31.58%	20	27.03%
Vestibulo-ocular reflex	16	29.09%	7	36.84%	23	31.08%
Visual perceptual functions						
Figure-ground segmentation	5	9.09%	0	0.00%	5	6.76%
Shape perception	6	10.91%	1	5.26%	7	9.46%
Movement perception	7	12.73%	1	5.26%	8	10.81%
Visual motor speed	9	16.36%	1	5.26%	10	13.51%
Visual motor speed/mental flexibility	14	25.45%	2	10.53%	16	21.62%
Visual motor speed/mental flexibility	14	25.45%	2	10.53%	16	21.62%
Lateralized visual attention/spatial cognition	4	7.27%	0	0.00%	4	5.41%
Visual constructive skills	8	14.55%	2	10.53%	10	13.51%
Visual search/grouping	4	7.27%	0	0.00%	4	5.41%
Visual load/crowding	13	23.64%	2	10.53%	15	20.27%
Simultanagnosia	4	7.27%	0	0.00%	4	5.41%
Visual spatial memory	4	7.27%	1	5.26%	5	6.76%
Object perception	8	14.55%	0	0.00%	8	10.81%
Cognitive functions						
Short term memory (span capacity), focused/sustained attention	12	21.82%	4	21.05%	16	21.62%
Working memory, focused/sustained attention	12	21.82%	4	21.05%	16	21.62%

Working memory, focused/sustained attention	12	21.82%	4	21.05%	16	21.62%
Short term/working memory, focused/sustained attention	12	21.82%	4	21.05%	16	21.62%
Verbal memory - encoding	16	29.09%	6	31.58%	22	29.73%
Verbal memory - retention	18	32.73%	6	31.58%	24	32.43%
Verbal fluency/executive functioning	13	23.64%	4	21.05%	17	22.97%
Anxiety symptoms	13	23.64%	5	26.32%	18	24.32%
Depression symptoms	13	23.64%	5	26.32%	18	24.32%

Note. PD = Parkinson's disease; RC+ = people with frequent reading complaints (often/always); RC- = people with infrequent reading complaints (never/hardly/sometimes)

Appendix D

Ophthalmological conditions in RC+ and RC-

Ophthalmological conditions in people with PD with frequent and infrequent reading complaints

	RC+		RC-	
	N	%	N	%
Cataract	9	16.4%	3	15.8%
Glaucoma	2	3.6%	1	5.3%
Macular degeneration	10	18.2%	1	5.3%
Macular abnormality	2	3.6%	1	5.3%
Corneal abnormality (including pterygium)	3	5.5%	0	0%
Dry eyes disease	4	7.3%	0	0%
Cloudy vitreous humor	0	0%	1	5.3%
Retinopathy	3	5.5%	1	5.3%
Eye movement disorder	1	1.8%	2	10.5%
History of melanoma in the eye	1	1.8%	0	0%
Blindness in one eye	1	1.8%	0	0%
Visual field defect	2	3.6%	0	0%
Missing	2	3.6%	2	10.5%

Note. Ophthalmic conditions assessed by an ophthalmologist at Royal Dutch Visio; PD = Parkinson's disease; RC+ = people with frequent reading complaints (often/always); RC- = people with infrequent reading complaints (never/hardly/sometimes)