Chapter

Training Reading Skills in Central Field Loss Patients: Impact of Clinical Advances and New Technologies to Improve Reading Ability

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Abstract

The primary goal of patients with central field loss attending to visual rehabilitation (VR) offices is to get adapted to daily life activities in near vision, mainly looking for recovering their ability to read again. The disparity in the functionality of these patients, due to the new advances in medical treatment and the increasing number of new apps and technological devices in the market, implies a heterogeneity in the reading training programs to be applied, and consequently a variability in the results obtained. Currently, with the increasing access to information and communication technologies and social networks, the opportunities for improving their access to information and communication is taken an important role. For this reason, the basis of ad-hoc evidence-based reading training programs is needed to standardized the clinical practice in reading rehabilitation for visual impaired and blind patients. This chapter will go in depth into these topics offering an exhaustive state of the art of reading rehabilitation for central field loss patients that will be useful for clinicians dedicated to the rehabilitation of visual impaired and blind people.

Keywords: visual rehabilitation, age-related macular degeneration, central field loss, eccentric fixation, saccades, optical aids, reading training, reading speed

1. Introduction

Reading is an extraordinarily sophisticated task that involves the synthesis of a number of different motor, sensory and cognitive functions [1]. Its proper performance largely depends on the state of the macula lutea and the optical pathway and visual cortex. Conditions affecting these areas such as age-related macular degeneration (AMD) and acquired brain injury (ABI) are frequent in the elderly and can compromise the reception or the conduction and processing of central visual information, with the consequent impairment of this ability, of great importance for the vocational, educational and daily life of the individual. Consequently, in low vision rehabilitation services, reading is the most common clinical complaint, as well as the primary goal for patients with central vision loss [1–3], whose prevalence is expected to increase in the coming years, as well as the diseases continues to rise in line with the aging of the population. Thus, improvement of reading performance in central vision loss patients is nowadays considered as one of the main objectives pursued by neuro-vision rehabilitation (NVR).

When the vision in the center of the visual field decreases, reading speed declines and oculomotor pattern differs compared with normal reading, showing an increase in the mean fixation duration and in the number of saccades [4, 5]. It is known that many of these individuals may eventually adopt one or more locations on the retinal periphery to serve as the preferred retinal locus (PRL). Therefore, for these patients, visual function is still malleable and able to adapt to unfavorable conditions [6, 7].

2. Development of visual rehabilitation and training in brief

When you hear the word blind or low vision, Braille system and the inability for the person to perform everyday tasks such as moving around comes to your mind [7].

If we trace a low vision timeline backwards in history, we can find that it is known that Marco Polo discovers elderly Chinese people using magnifying glasses for Reading (1270), and the first magnifying aid for visual defects attributed to Rene Descartes in 1637 [8]; But it is not until the nineteenth century that the LVR receives attention. In 1850, Amsterdam separately counts the number of inhabitants with impaired vision, Hermann von Helmholtz invents the ophthalmoscope (1851) and, in 1897, Charles Prentice invents the typoscope [8]. The beginnings of the current era can be said to have begun at the first international congress in low vision, sponsored by the American Foundation for the Blind, in 1986. In 1996, International Society for Low-vision Research and Rehabilitation (ISLRR) officially incorporated in Amsterdam [8]. By the mid-twentieth century, the first manuals including information on methods of visual rehabilitation were published. E. Faye was the first person to coin the term low vision.

In 1973, the first Low Vision Diplomate program established was registered within American Academy of Optometry first diplomate awarded Western Michigan University (USA) offers first required low vision course as part of orientation & mobility program Low Vision Clinical Society founded in the United States [8].

Currently, a person with distant visual acuity (VA) 0.3 or less (20/60 Snellen notation), a visual field of 10° from the point of fixation, and with reduced functionality is considered low vision [7]. This definition was not always universal, previously low vision was defined by a VA of 20/70 or less, however, it did not include the degree of functional defect. The subject's functionality may be affected (even in VAs greater than 20/70) by problems of loss of contrast sensitivity (CS) and glare [9].

In 2018, the International Classification of Diseases separated visual impairment into two groups: far and near. Thus, the near vision impairment is an VA lower than N6 or N8 at 40 cm with the existing correction. There are signs that worldwide the World Health Organization estimates that there are 1300 million people with visual impairment [10].

It should be noted that visual rehabilitation requires multidisciplinary work, which includes ophthalmologists, optometrists and visual therapists, in most cases psychologists and social workers work together.

The work of psychologists is important in those patients who are in a state of depression. Depression can be detected by optometrists or ophthalmologists through anamnesis and the use of questionnaires. Studies have found that people with vision loss have four times more depression than a person without visual impairment [11]. One of the main objectives of the visual rehabilitation service is to improve the functional capacity of each subject and the action plan must be adapted individually [12].

Visual rehabilitation, apart from improving the quality of life of subjects by increasing their functionality, avoids a series of events that can be triggered by their visual impairment. Among the events are: falls, being people with low vision more likely to suffer [13] and depression, which more than 30% of these subjects develop and show an improvement in VR by eliminating it [14].

3. Reading as one of the objectives of visual rehabilitation

Visual rehabilitation seeks to regain the skills of a person with visual impairment. This recovery is done gradually, using optical and non-optical aids, in addition to the strategies proposed by the visual therapist. The action of reading necessarily implies using the central retina. Therefore, a visual disability due to an ophthalmological pathology that affects the central visual field will significantly affect to the action of reading.

Several studies indicate that reading is one of the most important actions that visually impaired people want to recover [15, 16]. This task is usually the main objective in the elderly, children and adolescents with low vision.

Being referred to low vision service implies a loss of vision that can generate loss of functionality, and consequently the subject may be perceived as not very competent, which will influence his mental state. Such a state can influence the outcome of rehabilitation, which in turn can contribute to changing the way in which the subject views himself.

3.1 How do we read?

Every time we read, the eyes perform a sequence of movements. The ocular movements by which these jump from one stimulus to another are called *saccadic* movements. Normally in the reading process, they go from left to right, but sometimes there are movements in the opposite direction to change lines or to return to what was read, in which case they are called *regression* movements [17].

We call *fixation* to the pause between a saccadic movement and another, in which moment the information is extracted. The amount and duration of this fixation calculates the reading capacity of the subject. The reading speed serves to evaluate the reading ability of the subject; in a subject in normal vision, recognize from 7 to 11 characters in the fovea during fixation in the right half but four or five characters in the left half. In other words, it is called *visual span* to the number of letters that can be recognized without moving the eyes [17].

3.2 How does reading performance work in AMD patients?

In a subject with low vision restoring its functionality and independence has a lot of meaning. Reading is also important for those children or adolescents who suffer from low vision, these subjects need to continue schooling or simply enjoy reading as a leisure, remaining functional, independent and psychologically motivated. Our world has been designed for the reader, for those people who are able to interpret all the information that surrounds us. Reading is an activity that affects all the orders of daily life, from access to the content of a letter or a medicine label, to the buy of a product or the information that we can find in the street or in a public building.

The Johns Hopkins Wilmer Eye Institute study showed that 60% of patients referred to low vision report that the main reason for consultation is the difficulty to read, other studies such as, see [18, 19] give similar results. There are also studies on age-related macular degeneration (AMD), the most common pathology that causes severe disability in the western world, where they mention the increase in emotional state, cognitive and quality of life of patients by improving the speed of reading [20].

When a person cannot use the fovea, all eye movements involved in the reading process are affected and as a consequence performance decreases considerably; other daily activities are also affected. Understanding that there are ophthalmological pathologies that affect the central field of vision, it is necessary to use the peripheral retina. Subjects use a region of para-central retina, normally less than 20° from the damage fovea [21]. This retinal place to use is known as preferential retinal locus (PRL). This PRL gives the ability to perform the function of the damaged central retinal area, can be trained and used for activities such as reading. In short, it is necessary to evaluate the PRL, know its location, characteristics (a microperimeter offers a precise method for this action) and from then on use optical and non-optical aids to rehabilitate the reading. Studies show that the use of microperimetry for rehabilitation generates improvements in visual acuity, fixation stability and reading speed.

When central field loss (CFL) is present, saccadic movements are erratic, with constant regression movements; fixation is very unstable and, as a consequence, perceived information is scarce and partial. All this affects two fundamental aspects for a satisfactory reading: reading speed and reading comprehension. In order to assess reading ability, these aspects must be measured. One of the goals of visual rehabilitation is to help the subject establish their own PRL as well as learn to use it efficiently. Sometimes the person has more than one PRL, and may even use it consciously or unconsciously.

Other aspects that affect the reading process and are involved in rehabilitation are the effect of crowding, which together with the visual span, present a correlation that is clarifying; reducing crowding enlarge the visual span and can facilitate reading [22].

4. Medical and technological advances for patients with central field loss

4.1 Central field loss pathologies

Central field loss is associated with macular diseases. Examples of these diseases are age-related macular degeneration, macular hole, macular edema and diabetic retinopathy [23]. In general, patients with these pathologies have preserved peripheral vision. As central vision is affected, reading or face recognition are affected. Rehabilitation strategies and visual aids are focused on those tasks.

4.2 Therapeutic strategies

In atrophic diseases, there is not a specific treatment, so actions are directed to prevention and in advanced cases, rehabilitation. In exudative diseases such as exudative AMD, there has been a wide range of treatments, including laser, radiation and anti- vascular endothelial growth factor (VEGF) therapy [24].

Laser photocoagulation was the first treatment for exudative AMD from 1979 [24]. This treatment stopped neovascularization progression, but laser burned retinal tissue, so patients with macular neovascularization could not be treated [24, 25]. This technique consisted in impacting with a laser on the retina to produce heat and that the proteins coagulate in order to slow down the appearance of neovases [26].

Another therapeutic strategy is radiation. This procedure attempts to affect the angiogenesis of choroidal neovases either directly by destroying endothelial cells and cytokines or indirectly on genes that regulate the action of cytokines. It can be administered by brachytherapy directly on the affected tissue; or by teletherapy administering the isotope externally [24]. It can be combined with anti-VEGF therapy [27].

With photodynamic therapy a photosensitive substance is injected in vein in order to activate it with a laser at a choroidal vessels level. In 1999, the efficacy of photodynamic therapy to stop choroidal neovascularization was tested, as well as the maximum and minimum doses to achieve the desired effect, being 150 and 25 J/cm^2, respectively [24].

Repeated intravitreal injections of anti-VEGF drugs are currently the most widely used treatment in AMD. VEGF is an angiogenic and vasculogenic factor; that is, it is involved in the formation of new vessels from existing ones and in the formation of embryonic vessels; as well as in their reappearance [28]. Several drugs had been developed, such as pegaptanib, bevacizumab, ranibizumab and, recently aflibercept. However, these anti-VEGF drugs only are trying to slow down the progression, they are not able to reverse the effect of the disease [25].

4.3 Optical coherence tomography (OCT): advances in screening technology

OCT is a diagnostic and control technology based on the principle of Michelson interferometry whereby light is divided into two optical pathways to the eye and a mirror. Thanks to this we can analyze the posterior retina, the macula, the papilla and the relations they have with the vitreous and the choroid [29]. The OCT Macular Cube 512 × 128 strategy allows, in addition to the analysis of macular layers, comparison with different measures in the same patient and comparison with the OCT database to establish whether the values are within normal or not, analyzing the macula in nine areas, being a central and two rings with four layers each (**Figure 1**). By means of this strategy, an area of 6 × 6 mm is measured using 128 A-Scans with 512 B-Scans.

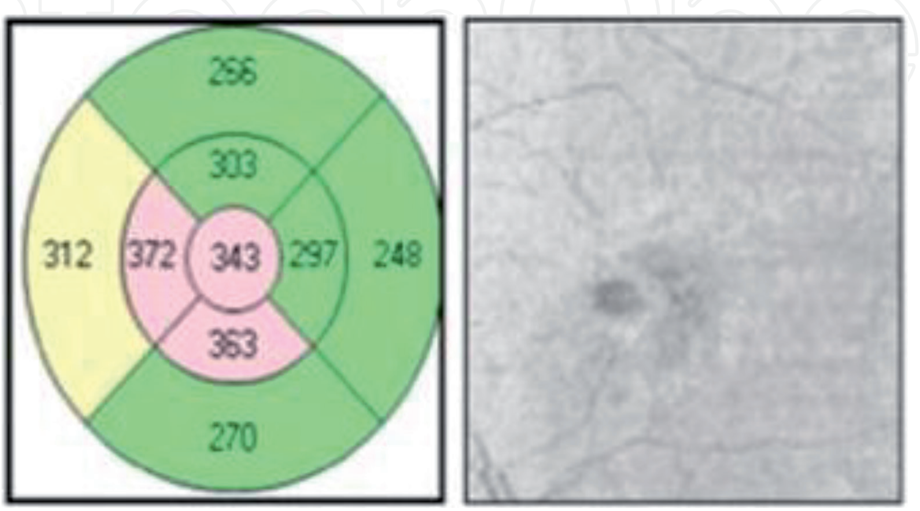

Figure 1.
An example of the nine analysis areas of macular cube strategy (from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4478143/).

5. Terminological problems

The term low vision was coined in the 1950s to convey the idea that vision can vary between the extremes of sighted and blindness [30]. Low vision generally refers to any chronic form of visual impairment that cannot be corrected with eye glasses, contact lenses, medical treatment or surgery and that negatively affects daily function of the individual [31, 32]. Although there is no universally accepted definition of "low vision," it is globally conceived as visual acuity of less than 0.3 (6/18) but equal or better than 0.05 (3/60) and/or visual field loss of less than 20 degrees in the better eye with the best possible correction [33].

This is based on the 10th revision of International Classification of Diseases derived from a World Health Organization Study group on the Prevention of Blindness that was convened in 1972 to provide a standardized definition to facilitate the data collection of population on prevalence of vision impairment and blindness.

Traditionally, low vision has been known by other numerous names such as partly sighted or subnormal vision, concepts that have already been outdated.

In 2002 at the 29th International Congress of Ophthalmology, the International Council of Ophthalmology (ICO) adopted a resolution where the following terminology was recommended [33, 34]:

- Blindness: to be used exclusively for total vision loss and for conditions where individuals have to rely predominantly on vision substitution skills.

- Low vision: to be used for lesser degrees of vision loss, where individuals can be helped significantly by vision enhancement aids and devices.

- Visual impairment: to be used when the condition of vision loss is characterized by a loss of visual functions, such as visual acuity or visual field, at the organ level since "impairment" is defined as any loss or abnormality of psychological, physiological or anatomical structure or function. Many of these functions (for example, visual acuity) can be measured quantitatively and in each eye separately.

- Visual disability: to be used when the condition prevents the undertaking of specific visual tasks, for example, loss of ability to read, since "disability" is defined as any restriction or lack resulting from an impairment of the ability to perform an activity in a manner or within a range considered normal.

- Visual handicap: to be used when the condition is described as a barrier to social participation (for example, loss of a driving license), since handicap is defined as a disadvantage for a given individual resulting from a disability or impairment that limits or prevents the fulfillment of a role that is normal for that individual (depending on age, sex and cultural factors).

- Functional vision: to be used when the vision loss is defined in terms of the individual's abilities with regard to activities of daily living (ADL). Thus, it applies to the individual and not to the visual system.

6. Current situation and its problems

Several research pieces have attempted to improve reading performance in people with central vision loss. Some authors have proposed to determine the mode of text presentation that offers these patients the fastest reading speed [35, 36] while others have suggested to examine whether simple manipulations of text typography or text typesetting (such as increasing letter or line spacing) could enhance this ability [37, 38]. Unfortunately, most of these studies did not found statistically significant differences in reading speed for different text presentations or when text typography or text typesetting were modified.

To date, only measures that have led to modest gains in reading speed among this group of people have been magnified font size, increased lighting and contrast conditions and the provision of optical magnifiers [39–41]. More recently, some works have established that reading performance on retinal periphery may benefits from perceptual learning based on certain tasks that include training in reading or identifying random letters sequences at various points across the visual field, although considerable individual variability was found in the results obtained from these investigations [42, 43].

As well as until the 1970s of the last century, people with low vision were rehabilitated as people with blindness, it is from that moment on that the magnification of texts and especially the use of optical and electronic aids allowed the development of the specific field of visual rehabilitation. The introduction of microscopes, magnifiers, telescopes and filters, together with the use of lecterns and adequacy of lighting, have allowed the development of a complete body of knowledge concerning to the new skills implemented when the person with CFL reads. The same can be said of electronic aids such as close-circuit television (CCTV) magnifiers and electronic magnifiers, which provide improved contrast and magnification that common optical aids of this type. These tools can be available mounted on a stand, head-mounted or hand-held.

As technological progress advances, numerous software apps and tech devices emerge to meet the reading needs of low-vision population. The production and distribution of digital documents was the beginning of harnessing technological advances for the visually impaired and brought new opportunities for reading improvement by allowing customization of lighting, contrast and font size variables to optimize the text display on the screen [44].

We are talking about software that magnify and provide contrast improvements or text to speech reproductions, compatible with computers and tablets, as well as the tablets and electronic books themselves, which thanks to the options they offer of brightness control, contrast, selection of type and font size, have been an important progress for people with AMD, and has enabled them to have free access to information.

At present, high-tech digital image enhancement programs are under study to provide better visualization for central vision loss patients. They represent an important challenge due to the change of model that they offer in the intervention in visual rehabilitation. It is necessary at this point to expand the reach and depth of research related to the use of these devices and software for reading.

A very relevant innovation is retinal implants; this is a prosthetic system that performs a process that captures the image, processes it and transforms it into electrical impulses and stimulates the retina's ganglion cells (RGCs) [45]. It appears to increase vision with acceptable safety profiles, even though the amelioration of functional vision generated by the prosthesis nowadays remains limited [46]. But it is still hopeful and promising in degenerative retinal diseases, and will surely bring a major challenge in the rehabilitation of these persons.

7. Theory of reading performance

Comprehensive reading is a tremendously complex activity. Although for skillful readers, it is a task that does not seem to offer too many difficulties, and proof of this is the speed with which it is read (between 150 and 400 words per minute), the truth is that in such a short time several cognitive operations have to be carried out [47].

Reading is only possible if a good number of cognitive and visual operations function properly. It has been verified that the reading system is made up of several separable, relatively autonomous modules, each of which oversees carrying out a specific function. Specifically, four modules or processes are distinguished: perceptual processes, lexical processing, syntactic and semantic [48].

7.1 Perceptual processes

The first step for the reading is the perception of the text, the recognition of the word, opening here a question: is each letter identified separately or is the word identified in its entirety? Already in 1972, Gough found that it was easier to find or recognize a letter when it was part of a word than when it was isolated in a random series of letters [49]. On the other hand, it is possible that both theories have their share of reason and that using the letter or the global word as a processing unit depends on the task, the context, the characteristics of the word and the reader's skill [50]. Also, spacing is important in reading speed. It has been proved that increasing letter spacing has a negative effect on reading speed in experienced adult readers;

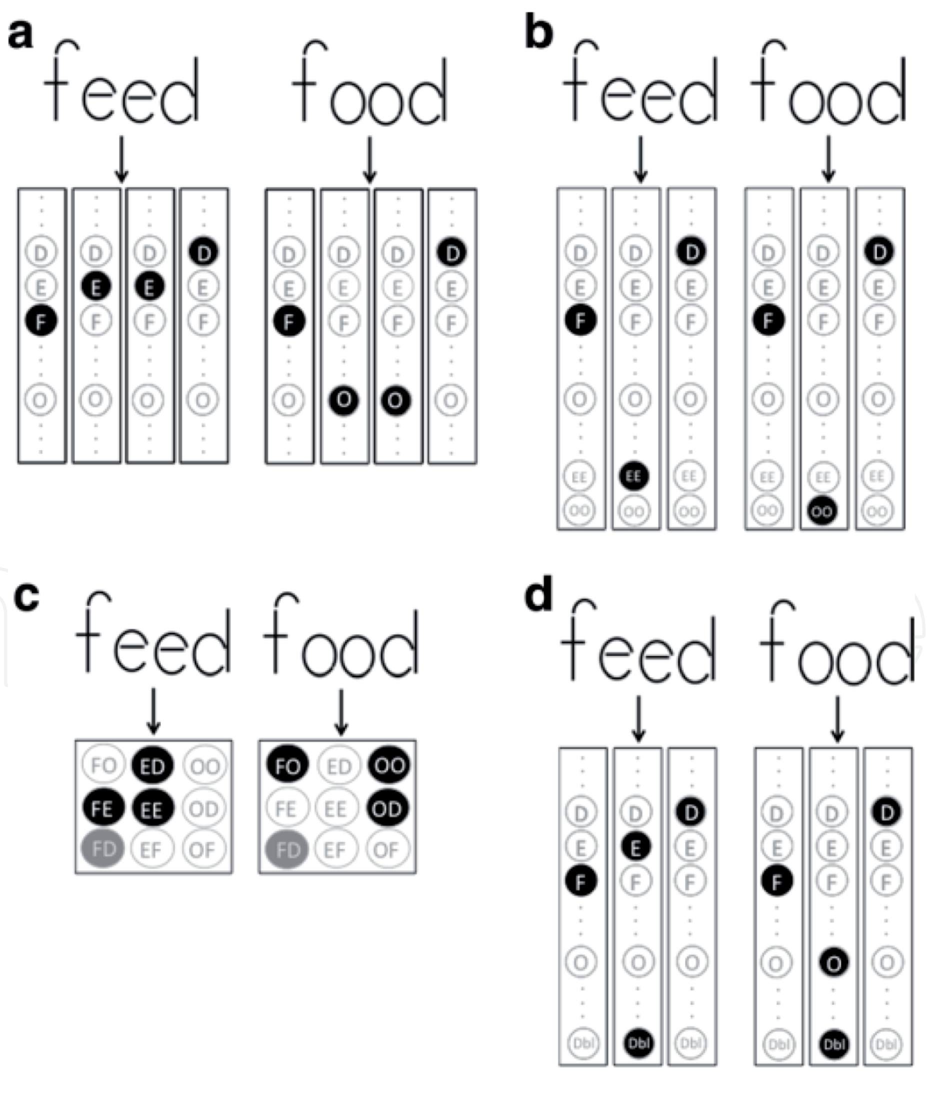

Figure 2.
Orthographic representations in various theories of visual word processing of the words feed and food [52]. (a) Representation of letter identify and order theories. (b) Theory of grapheme identification. (c) Open bigram theory. (d) Separation of letter identity and letter doubling information theory (from https://link.springer.com/article/10.3758%2Fs13423-016-1149-8).

while in children has no effect [51]. On the other hand, Fischer-Baum researched word identification, taking special focus on double letters [52]. He also noticed that a patient with acquired dyslexia used to spell words in a similar way as a previous spelt word, including double letters [53]. He found that letter identity and double letters are separately represented in written language, showing a complex reading capacity and a common orthographic representation of reading and writing (**Figure 2**).

Eye movements and fixations are involved in the perceptual process. The information we extract passes into iconic memory, of great capacity but short duration. The information is transferred from iconic memory to short-term visual memory, which allows it to be maintained for a longer period of time and is now retained as linguistic material. Finally, a comparison is made with the long-term memory to check whether the word is stored [47].

7.2 Lexical processing

The next step is the recognition of the meaning of the word, a process that can be done in two ways. One of them is to compare the spelling of the word with a series of representations stored in the memory to see which one fits. All that is needed is the existence of a word store or mental lexicon in which all the words known to the reader are represented [53]. Reading by this route involves several operations: the visual analysis of the word that is transmitted to a store of orthographic representations of words called "visual lexicon", where it is identified by comparison with the units stored there. This in turn will activate the corresponding phonological representation, located in another lexical warehouse, the so-called "phonological lexicon", and from here it will be deposited in the "pronunciation warehouse" ready to be issued. This route is known by the name of lexical route or also visual route [53].

7.3 Syntactic processing

We talk about the process of understanding how words are interrelate to each other. Isolated words do not convey any new information, but it is in the relationship between them that the message is found [54]. Once the words of a sentence have been recognized the reader must determine how they are related to each other. The parsing process therefore comprises three main operations [55], by means of which the areas to which the words correspond are labeled, the relationship between the components is established and a structure is constructed according to the hierarchy of its components.

7.4 Semantic processing

In this process, once the meaning of the sentence has been extracted, it is integrated and compared with previous knowledge; therefore, the richness of the person's vocabulary and previous experience will be decisive. The process ends when extracted meaning is integrated into memory, with the rest of the reader's knowledge. During this process, the reader makes certain inferences, makes deductions about the information and adds non-explicit information. This last phase of the process is the most complex but it is not carried out independently of the previous ones, but all the processes interact with each other [47].

When assessing reading comprehension, sometimes independent phrases are used, outside of a story or context. If there are no given part, the sentences could not be understood as we do not know what facts they refer to. If, on the other hand, there are no new parts, they would not provide any knowledge other than that which is already possessed [49].

8. Updated reading skills development strategies

8.1 Introduction

Reading is one of the most important visual activities, requiring complex cognitive processes. One of the most important reading skills is reading speed, being critical to understand the reading text. But achieving an adequate reading speed for compression requires mastery of the various eye skills and movements described above. The stimulus required for an optimal reading is also important. Its parameters are: characters size subtending 0.3–2°; field size up to 4 characters independent of character size; bandwidth up to 2 cycles/degree independent of character size; and 1 spatial-frequency channel suffices for reading [3]. Visual spam requires 7–11 characters to be recognized at the fovea for normal reading rates during fixation [56]. It is well-known that the maximum visual acuity is located in the fovea and decreases directly with eccentricity [57].

In a meta-analytic study, reading skills components were evaluated to determine their importance on reading comprehension in healthy adults. Results showed a great relationship between comprehension and the following skills: morphological awareness, language comprehension, fluency, oral vocabulary knowledge, real word decoding and working memory [58].

This section will address the assessment of cognitive skills in a rehabilitation program, the eccentric viewing training, the optical correction and other training techniques such as oculomotor control and perceptual training.

8.2 Cognitive skills

Assessment of cognitive skills is the step prior to the development of a visual rehabilitation program. Several tests are used for cognitive skills evaluation, such as MoCA, MMCT or CDT [59] or the scale COGEVIS, which is specially designed for low vision patients [60]. Also, it is essential to evaluate the level of literacy of the patient before visual and reading evaluation. If the patient is illiterate or has a low level of reading comprehension, it may be useful the tumbling E test for visual acuity [3].

8.3 Eccentric viewing training and preferred retinal loci (PRL)

Eccentric viewing consists of using a non-central part of the retina for viewing. In this method of vision, given when central retina is damaged, the eye uses an eccentric retinal location, known as preferred retinal loci (PRL) [61]. It is common for many patients with eccentric viewing not to realize that they are fixing in that way. According to Jeong and Moon, no improvements were found in best corrected visual acuity after 2 weeks of self-training; however, there were significant improvements in reading speed and satisfaction scores [61].

Nowadays, microperimeters can evaluate the visual field and the PRL even in patients without fixation, correlating the exact retinal locations with the visual field [62]. There are two microperimetry techniques: static and dynamic. The first of these can detect mild scotomas and defining their shape, with no movement of the stimulus. In dynamic microperimetry, the stimulus moves from the periphery towards the point of fixation, presenting difficulties in identifying the relative scotomas [7].

Sometimes PRL is not located in an appropriate area and it should be relocated in a better retinal location, closer to the fovea so visual acuity will be the best [7]. Some studies have shown that patients trend to develop the PRL at the left side of the atrophy [63]. However, Greenstein et al. evaluated several patients with macular disease such as AMD and Stargardt disease, founding a majority of PRL located above the atrophic lesion [64]. A superior or inferior location of the PRL is better than a left location for reading because scotoma does not interfere much in continuous reading.

In some patients, oculomotor deficits can reduce reading skills, so training methods with using eye movements are needed for these patients. It is the case of Rapid Serial Visual Presentation (RSVP) training, which allows PRL training without eye movements to read. The words of the sentence are presented one by one at the center of the screen, allowing reading without eye movements because fixation with the PRL is maintained on the screen [3].

8.4 Optical correction and the use of prisms

Optical correction plays a very important role to make the most of patients' vision. Nevertheless, optical correction is not only optical lenses with the correction of patients' refractive error, but also adds power for reading distance and prisms if necessary [65].

As a field defect, prisms can be used for AMD patients. Several studies have been conducted to determine the benefits of repositioning the retinal image in its PRL, the area of the retina where the subject looks and replaces the pitting, using prisms in patients with macular degeneration. Three different studies evaluated the use of prisms in subjects with AMD, shifting the image from the visual field to the PRL predetermined by the subject for rehabilitation [66–68]. Visual acuity was assessed with the best correction, obtaining significant values of improvement with the use of prisms. In addition, the PRL preferred by patients was mostly in the upper retina and showed conformity and adaptation to the use of prisms in the three studies. This indicates that the use of prisms, with good PRL delimitation, may be an appropriate rehabilitation option for patients with AMD.

8.5 Training materials and devices

First of all, we must make a distinction between optical devices and non-optical devices for low vision patients. An optical aid is an optical system made up of high-powered lenses that help people with reduced vision make the most of their remaining vision. On his behalf, a non-optical aid, such as light flexes or lecterns, is a complement to help make the most of vision. For reading, spectacles magnifiers and hand and stand magnifiers are the most classical optical aids used; while macro types, lecterns and an appropriate illumination are the non-optical aids most important for central vision loss patients [7]. Filters are used in patients suffering from photophobia and glare and they have a great visual impact in macular disease patients [7]. Over the years several studies have shown the effects of filters on glare, but there is no global filter prescribing protocol for each disease [69–71]. One of those studies found that with a blue-violet filter, patients with central and peripheral scotoma improved visual acuity, contrast sensibility and glare better than the yellow filter [71].

Contrast plays an important role on training reading skills. Reading materials should have a 100% black and white contrast and reading conditions should reduce the amount of glare, specially created by short wavelength light. Also, light position is a crucial point to be considered, being recommendable that light source is placed above or behind the patient [3]. Finally, text font is also important. In a Canadian research with patients with AMD, Courier text font was found as the most recommendable font for these patients, whereas Arial was found as the worst for reading smaller print [72].

8.6 Oculomotor control training

It is necessary to train eye movements, saccades and fixation stability in order to rehabilitate reading performance. The flashlight technique is useful to train oculomotor movements and fixation stability on distance targets. The patient holds a flashlight and, keeping their head still, follows the light with their eyes. A test variation uses a laser pointer directed to the wall as a stimulus, which allows the patient to detect relative scotomas [3]. The King-Devick test (KDT) for low vision patients is an advanced training of fixation stability, saccades and tracking eye movements. It is based on performance of rapid number naming. In a 6 weeks research with KDT training in first and second grade children, the treatment group improved significantly compared with the control group in reading fluency and reading comprehension, with efficient eye movements [73].

8.7 Perceptual training

Perceptual training is the last step of the rehabilitation program. Then, an example of a protocol is shown [3]:

- Start with large print: it is important to start with large print and, to decrease the size as the patient improves his or her reading skills. If it is possible, the ideally size is comparable with a newspaper print (size 1 M).

- Start reading single letters: its aim is to get the patient to recognize each letter and number detail with eccentric vision for, then, explore simple words. At the end of this process, the patient may be capable of reading a continuous text.

- Use training to improve comprehension: this can be possible by providing the patient reading material with higher levels. Improving reading speed a comprehensive rehabilitation can be achieved.

- Transfer acquired reading skills into daily life activities.

9. Assessment and individual reading rehabilitation plan

Visual impaired patients require an individualize assessment and rehabilitation plan due to the affectation by their pathology varies from one patient to another. This fact makes it difficult to develop a standardized attentional plan for these patients. However, several assessment guidelines for central vision loss patients can be recommended.

Firstly, fluent reading requires a minimal visual acuity of 20/50, a visual field at least of 2° to the right and the left and a holding position of 250 ms between saccades [74].

Nowadays, microperimetry is one of the most important tests in patients with central vision loss. The origin of microperimetry is due to the need to evaluate the visual field in people with unstable or extrafoveal fixation problems or because of problems in the macula. Conventional perimetry is based on the fixation of the subject. If the fixation is extrafoveal and/or unstable, the visual field will not be correct, with values displaced from their true location and incorrect scotoma sizes [75]. Microperimetry allows the points of the visual field to be correlated with the exact retinal location; at the same time, the fundus of the eye can be visualized while visual stimuli are projected [62] (**Figure 3**). It allows also eccentric fixation training.

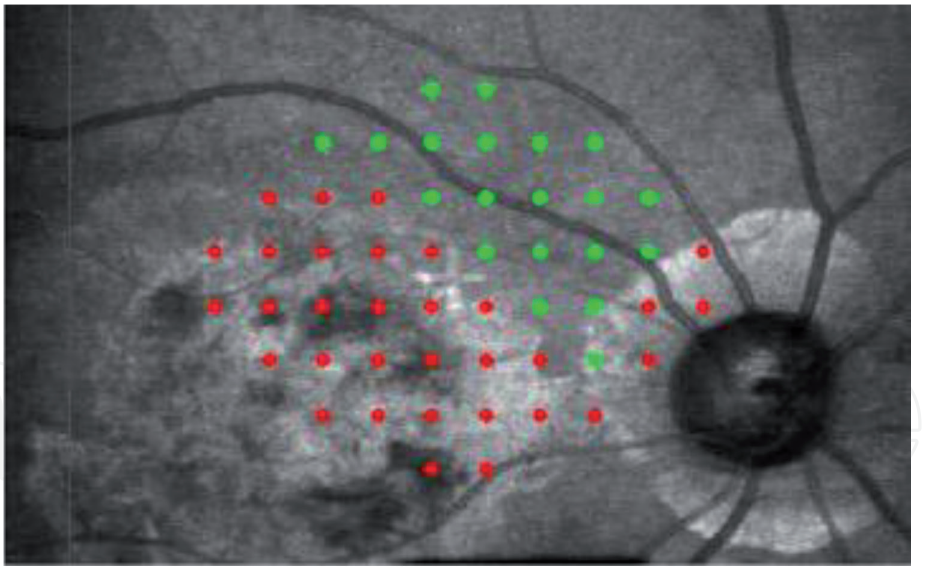

Figure 3.
Microperimetric image in which the evaluated points and the anatomical situation in the fundus of the eye are observed (from https://www.canadianjournalofophthalmology.ca/article/S0008-4182(13)00209-3/fulltext).

In macular abnormalities, microsacadic movements are greater than in a normal eye, affecting fixation stability [76]. Due to poor fixation stability, the reading speed is affected and reduced [77]. This fixation stability can be improved by training, and microperimetry is essential for such training.

An important consequence of central vision loss in some patients is depression, which has a prevalence of 2–5% [78]. Low-vision rehabilitation aids have shown to improve reading speed but no effects on depression have been reported in AMD patients [79]. If traditional rehabilitation protocols do not show a great impact on depression, prevention of depression may be an appropriate action. The sum of visual rehabilitator, behavioral activation and occupational therapist has shown an effective effect on depression.

An improvement on quality of life and reading has been seen in AMD patients who already use magnifying aids, after a computer-based reading training at home [78]. On that randomized and controlled trial, patients were divided into two groups: primary reading training group and control group with placebo training. Control group started with reading training after 6 weeks of placebo, which consist of crossword puzzles. Reading speed was measured with the German version of the International Reading Speed Texts (IReST), eye movements were measured with a scanning lases ophthalmoscope (SLO); and degree of depression, cognition and quality of life were measured with Montgomery-Asberg Depression Rating Scale (MADRS), dementia detection test (DemTect) and Impact of Vision Impairment (IVI) questionnaires, respectively. Reading speed improved in training group, as well as emotional status. Such results were not given in the control group [78].

10. Innovative reading rehabilitation strategies and devices: assistive devices and technology

With the development of technology, a new field of rehabilitation opened up, beginning with the first electronic aids. Tablets and iPads are currently widely used, even in elderly AMD patients. It has been shown in these patients that they read faster on iPad with larger text sizes when compared with paper. Also, patients reported to have the best clarity with it [80]. Moreover, it has been proved to improve reading speed in low vision patients, as well as other low vision devices such as closed-circuit television (CCTV); being the previous experience with an iPad decisive in order to obtain greater reading speeds [81].

10.1 Head-mounted display

Another technological aids can be a virtual bioptic telescope and a virtual projection screen, implemented in a head-mounted display (HMD) [82]. In this research, two new magnification strategies were developed: a virtual bioptic telescope and a projection screen presented in virtual reality. The first one consists of a user-defined region of a wide-field binocular head-mounted display where the image can be magnified (**Figure 4**). With this system, visual function was significantly improved, including reading. The minimum clinically important difference (MCID) frequency in reading task was 85.7% of participants [82], which shows an appropriated visual aid for central vision loss patients.

10.2 Intra-ocular telescopic implants

Intra-ocular telescopic implants are commercially invasive aids for low vision patients. Dunbar and Shawahir-Scala review showed the different implants available on the market for patients with AMD [83]. These implants consist of intra-ocular lens combined in order to create an optic system. Lipshitz mirror implant (LMI) is a modified conventional intra-ocular lens (IOL) with two miniature mirrors in a combination that creates a dual optical system in a similar way to multifocal IOL. The central part of the IOL magnifies the image while the peripheral portion remains unmagnified. Quality of life improved and single letter near acuity with early treatment diabetic retinopathy study (ETDRS) near vision chart at 20 cm improved [84]. With the same optical basis of a multifocal IOL, the Scharioth Macula Lens (SML) has a central optic zone with +10.00 D addition. Compared with a +6.00 D spectacle lens for near vision, SML reported 2.1 lines better visual acuity at 15 cm than the spectacle lens at 1 month [85]. Similar results to those of LMI were obtained with IOL-AMD after 4 months. This implant consists of a Galilean telescope in one eye with two hydrophobic IOLs, one negative and one positive [83]. Finally, the intra-ocular miniaturized telescope (IMT) takes advantage of corneal optical power. It is implanted in one eye, used for near vision, while the other eye is used for distance vision. At 1 year, 3.2 lines of improvement in near vision acuity in ETDRS was reported compared with baseline, remaining after 5 years of surgery [83, 86].

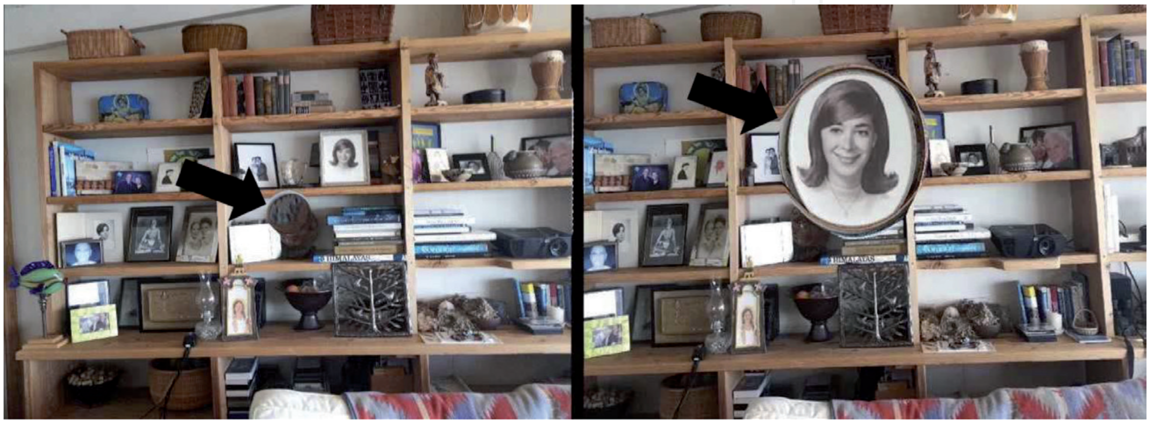

Figure 4.
Example of the user-defined region or "bubble" where image can be magnified [82] (from https://tvst.arvojournals.org/article.aspx?articleid=2725386).

10.3 Gaming and electronic devices

Relying on the development of technology, games have also undergone a revolution. Today, there are multiple games that can be played on iPad. AMD patients in a large percentage use personal electronic devices for playing games [87]. Due to these results, gaming could play an important role in earlier detection of AMD. Video games had been used to train visual acuity, fixation pattern and retinal sensitivity in patients with Stargardt disease [88]. Patients of this study played action video-game during 1 h per day each eye with alternate patching. Results showed an improvement of these visual functions, which opens a new option of rehabilitation based on video-games.

11. Conclusions

Reading involves the participation of different perceptive and cognitive processes. When a person suffers a pathology such as AMD, the vision in the central visual field is reduced and all the processes are altered, being necessary a rehabilitative intervention that determines the scope of the visual loss, helps to establish a new point of visual fixation and trains in the ocular movements, so that the reading becomes fluid and comprehensive. In this rehabilitative process, it is necessary to implement optical and non-optical aids that improve the visual functioning of the person affected by AMD. New electronic devices and access to digital information are producing changes in the visual rehabilitation strategies of people with AMD.

Conflict of interest

None of the authors have any conflict of interest on the devices or technology described in this chapter.

Abbreviations

ABI	acquired brain injury
ADL	activities of daily living
AMD	age-related macular degeneration
CCTV	close circuit television
CFL	central field loss
CS	contrast sensitivity
CVF	central visual field
ETDRS	early treatment diabetic retinopathy study
HMD	head-mounted display
ICO	International Council of Ophthalmology
IOL	intra-ocular lens
IMT	intra-ocular miniaturized telescope
IReST	International Reading Speed Texts
ISLRR	International Society for Low-vision Research and Rehabilitation
IVI	impact of vision impairment
KDT	King-Devick test
LMI	Lipshitz mirror implant
LVR	low vision rehabilitation
MADRS	Montgomery-Asberg Depression Rating Scale

MCID	minimum clinically important difference
NVR	neuro visual rehabilitation
OCT	optical coherence tomography
PRL	preferred retinal locus
RSVP	rapid serial visual presentation
RGCs	retinal ganglion cells
SLO	scanning laser ophthalmoscope
VEGF	vascular endothelial growth factor
VA	visual acuity

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References

[1] Kanonidou E. Reading performance and central vision loss. Hippokratia. 2011;**15**:103-108

[2] Chung ST. Enhancing visual performance for people with central vision loss. Optometry and Vision Science. 2010;**87**:276-284. DOI: 10.1097/OPX.0b013e3181c91347

[3] Markowitz M, Daibert-Nido M, Markowitz SN. Rehabilitation of reading skills in patients with age-related macular degeneration. Canadian Journal of Ophthalmology. 2018;**53**:3-8. DOI: 10.1016/j.jcjo.2017.10.042

[4] Rainer K. Eye movements in reading and information processing: 20 years of research. Psychological Bulletin. 1998;**124**:372-422

[5] Bullimore MA, Bailey IL. Reading and eye movements in age-related maculopathy. Optometry and Vision Science. 1995;**72**:125-138

[6] Crossland MD, Culham LE, Kabanarou SA, Rubin GS. Preferred retinal locus development in patients with macular disease. Ophthalmology. 2005;**112**:1579-1585. DOI: 10.1016/j.ophtha.2005.03.027

[7] Coco Ma B, Herrera J. Manual de Baja Visión y Rehabilitación Visual. Madrid: Médica Panamericana; 2015

[8] Goodrich G, Arditi A, Rubin G, Keeffe J, Legge G. The low vision timeline: An interactive history. In: International Low Vision Conference (ISLRR); 7-11 July 2008; Montreal, Canada: Visual Impairment Research. 2008. pp. 67-75

[9] World Health Organization. Consultation on development of standards for characterization of vision loss and visual function [Internet]. 2003. Available from: https://apps.who.int/iris/bitstream/handle/10665/68601/WHO_PBL_03.91.pdf;jsessionid=8AD5F022F7989A5B11635CD79330BE0D?sequence=1 [Accessed: 05 June 2019]

[10] World Health Organization. Ceguera y discapacidad visual [Internet]. 2018. Available from: https://www.who.int/es/news-room/fact-sheets/detail/blindness-and-visual-impairment [Accessed: 05 June 2019]

[11] NIH Consensus Development Conference. Diagnosis and treatment of depression of late life. JAMA. 1992;**268**:1018-1029

[12] Dagnelie G. Age-related psychophysical changes and low vision. Investigative Ophthalmology & Visual Science. 2013;**54**:88-93. DOI: 10.1167/iovs.13-12934

[13] Shen SH, Huang KC, Tsai YH, Yang TY, Lee MS, et al. Risk analysis for second hip fracture in patients after hip fracture surgery: A nationwide population-based study. Journal of the American Medical Directors Association. 2014;**15**:725-731. DOI: 10.1016/j.jamda.2014.05.010

[14] Nollett CL, Bray N, Bunce C, Casten RJ, Edwards RT, et al. Depression in visual impairment trial (DEPVIT): A randomized clinical trial of depression treatments in people with low vision. Investigative Ophthalmology & Visual Science. 2016;**57**:4247-4254. DOI: 10.1167/iovs.16-19345

[15] Coco-Martin MB et al. Design and evaluation of a customized reading rehabilitation program for patients with age-related macular degeneration. Ophthalmology;**120**(1):151-159. DOI: 10.1016/j.ophtha.2012.07.035

[16] Owsley C, McGwin G Jr, Lee PP, Wasserman N, Searcey K. Characteristics of low-vision rehabilitation services

in the United States. Archives of Ophthalmology. 2009;**127**:681-689. DOI: 10.1001/archophthalmol.2009.55

[17] Legge GE, Cheung SH, Yu D, Chung T, Lee HW, et al. The case for the visual span as a sensory bottleneck in reading. Journal of Vision. 2007;**7**:1-15. DOI: 10.1167/7.2.9

[18] Crossland MD, Gould ES, Helman CG, Feely MP, Rubin GS. Expectations and perceived benefits of a hospital-based low vision clinic: Results of an exploratory, qualitative research study. Visual Impairment Research. 2007;**9**:59-66. DOI: 10.1080/13882350701643582

[19] Friedman SM, Munoz B, Rubin GS, West SK, Bandeen-Roche K, et al. Characteristics of discrepancies between self-reported visual function and measured reading speed. Salisbury eye evaluation project team. Investigative Ophthalmology & Visual Science. 1999;**40**:858-886

[20] Mielke A, Wirkus K, Niebler R, Eschweiler G, Nguyen NX, et al. The influence of visual rehabilitation on secondary depressive disorders due to age-related macular degeneration. A randomized controlled pilot study. Der Ophthalmologe. 2013;**110**:433-440

[21] Cheung SH, Kallie CS, Legge GE, Cheong AM. Nonlinear mixed-effects modeling of MNREAD data. Investigative Ophthalmology & Visual Science. 2008;**49**:828-835. DOI: 10.1167/iovs.07-0555

[22] He Y, Legge GE. Linking crowding, visual span, and reading. Journal of Vision. 2017;**17**:11. DOI: 10.1167/17.11.11

[23] Kanski J. Oftalmología Clínica. Vol. 13. Elsevier; 2006. pp. 413-427

[24] Lim JI. Age-Related Macular Degeneration. 3rd ed. Taylor & Francis Group; 2013

[25] Ryan SJ. Retina. Vol. 3. Elsevier; 2013. pp. 1213-1214

[26] Gómez-Ulla F, Rodríguez Cid MR, Marín E. Fotocoagulación del edema macular y retinopatía proliferante. In: Retinopatía Diabética. Sociedad Española de Oftalmología; 2006

[27] Rating P, Freimuth MA, Stuschke M, Bornfeld N. Adjuvant radiotherapy during anti-VEGF in neovascular age-related macular degeneration. Der Ophthalmologe. 2017;**114**:370-374

[28] Andrini LB. Expresión del factor de crecimiento del endotelio vascular (vegf) durante la regeneración hepática [thesis]. Universidad Nacional de La Plata; 2010

[29] Courtney RJ, McClintic JI, Ehlers JP. Comparison of spectral domain optical coherence tomography scan patterns and clinical review strategies in neovascular aged related macular degeneration. Retina. 2015;**35**(7):1315-1322. DOI: 10.1097/IAE.0000000000000478

[30] Colenbrander A, Fletcher DC. Low vision rehabilitation: Basic concepts and terms. Journal of Ophthalmic Nursing & Technology. 1992;**11**(1):5-9

[31] American Academy of Ophthalmology. What is Low Vision?. 2019. Available from: https://www.aao.org/eye-health/diseases/low-vision [Accessed: 03 June 2019]

[32] Acosta R, Bentley SA, Giacomelli G, Allcock C, Evans JR, Virgili G. Reading aids for adults with low vision. The Cochrane Database of Systematic Reviews. 2018;**4**:CD003303. DOI: 10.1002/14651858.CD003303.pub4

[33] European Council of Optometry and Optics. Low Vision (Position Paper). 2011. Avaiable from: https://www.ecoo.info/2011/03/10/position-paper-low-vision/ [Accessed: 07 June 2019]

[34] International Council of Ophthalmology. Visual Standards: Aspects and Ranges with Emphasis on Population Surveys. 2002. Available from: http://www.icoph.org/downloads/visualstandardsreport.pdf [Accessed: 07 June 2019]

[35] Presentation formats. Optometry and Vision Science. 2004;**81**(3):205-213

[36] Fine EM, Peli E. Scrolled and rapid serial visual presentation texts are read at similar rates by the visually impaired. Journal of the Optical Society of America. 1995;**12**(10):2286-2292. DOI: 10.1364/JOSAA.12.002286

[37] Chung ST. The effect of letter spacing on reading speed in central and peripheral vision. Investigative Ophthalmology & Visual Science. 2002;**43**(4):1270-1276

[38] Chung ST, Jarvis SH, Woo SY, Hanson K, Jose RT. Reading speed does not benefit from increased line spacing in AMD patients. Optometry and Vision Science. 2008;**85**(9):827-833. DOI: 10.1097/OPX.0b013e31818527ea

[39] Rubin GS, Feely M, Perera S, Ekstrom K, Williamson E. The effect of font and line width on reading speed in people with mild to moderate vision loss

[40] Bowers AR, Meek C, Stewart N. Illumination and reading performance in age-related macular degeneration. Clinincal & Experimental Optometry. 2001;**84**(3):139-147

[41] Christen M, Abegg M. The effect of magnification and contrast on reading performance in different types of simulated low vision. Journal of Eye Movement Research. 2017;**10**(2):5. DOI: 10.16910/jemr.10.2.5

[42] Chung STL. Improving reading speed for people with central vision loss through perceptual learning. Investigative Ophthalmology & Visual Science. 2011;**52**(2):1164-1170. DOI: 10.1167/iovs.10-6034

[43] Chung STL, Legge GE, Cheung SH. Letter-recognition and reading speed in peripheral vision benefit from perceptual learning. Vision Research. 2004;**44**(7):695-709. DOI: 10.1016/j.visres.2003.09.028

[44] Legge GE. Reading digital with low vision. Visible Language. 2016;**50**(2):102-125

[45] Bloch E, Luo Y, da Cruz L. Advances in retinal prosthesis systems. Therapeutic Advances in Ophthalmology. 2019;**11**:1-16. DOI: 10.1177/2515841418817501

[46] Humayun MS, de Juan E, Dagnelie G. The bionic eye: A quarter century of retinal prosthesis research and development. Ophthalmology. 2016;**123**(10):89-97. DOI: 10.1016/j.ophtha.2016.06.044

[47] Cuetos VF. Psicología de la lectura. Madrid: Escuela Española; 2008

[48] Mitchell D. The Process of Reading. Chichester: John Wiley & Sons; 1982

[49] Gough PB. One Second of Reading. Cambridge: JF Cananaugh y IG Mattingly; 1972

[50] Just MA, Carpenter PA. A theory of reading: From eye fixations to comprehension. Psychological Review. 1980;**87**:329-354

[51] Weiss B, Knakker B, Vidnyánszky Z. Visual processing during natural reading. Scientific Report. 2016;**6**:26902

[52] Fischer-Baum S. The independence of letter identify and letter doubling in reading. Psychonomic Bulletin & Review. 2017;**24**:873-878

[53] Allport D. Components of the Mental Lexicon. London: P Kolers Ed; 1979

[54] Legge GE, Glenn A. Fry award lecture 1990: Three perspectives on low vision reading. Optometry and Vision Science. 1991;**68**:763-769

[55] Zurif EB, Caramazza A, Myerson R. Grammatical judgments of agrammatic aphasics. Neuropsychologia. 1972;**10**:405-417

[56] Legge GE, Mansfield JS, Chung STL. sychophysics of reading. XX. Linking letter recognition of reading speed in central and peripheral vision. Vision Research. 2001;**41**:725-743

[57] Chung STL, Mansfield JS, Legge GE. Psychophysics of reading. XVIII. The effect of print size on reading speed in normal peripheral vision. Vision Research. 1998;**38**:2949-2962

[58] TigheE,SchatschneiderC.Examining the relationships of component reading skills to reading comprehension in struggling adults readers: A meta-analysis. Learning Disability. 2016;**49**:395-409

[59] Killen A, Firbank MJ, Collerton D, Clarke M, Jefferis JM, Taylor JP, et al. The assessment of cognition in visually impaired older adults. Age and Ageing. 2013;**42**:98-102

[60] Meyniel C, Samri D, Stefano F, Crevoisier J, Bonté F, Migliaccio R, et al. COGEVIS: A new scale to evaluate cognition in patients with visual deficiency. Behavioural Neurology. 2018

[61] Jeong JH, Moon NJ. A study of eccentric viewing training for low vision rehabilitation. Korean Journal of Ophthalmology. 2011;**25**:409-416

[62] Fletcher DC, MacKeben M. Microperimetrycorrespondence.Everyday use of modern microperimetry in a low-vision service. Canadian Journal of Ophthalmology. 2013;**48**

[63] Rubin GS. Vision rehabilitation for patients with age-related macular degeneration. Eye. 2001;**15**:430-435

[64] Greenstein VC, Santos RAV, Tsang SH, Smith RT, Barile GR, Seiple W. Preferred retinal locus in macular disease: Characteristcs and clinical implications. Retina. 2008;**28**:1234-1240

[65] Markowitz SN. Principles of modern low vision rehabilitation. Canadian Journal of Ophthalmology. 2006;**41**:289-312

[66] Al-Karmi R, Markowitz SN. Image relocation with prisms in patients with age-related macular degeneration. Canadian Journal of Ophthalmology. 2006;**41**:313-318

[67] Markowitz SN, Reyes SV, Sheng L. The use of prisms for vision rehabilitation after macular function loss: an evidence-based review. Acta Ophthalmologica. 2013;**91**:207-211

[68] Reyes SV, Silvestri V, Amore F, Markowitz SN. Use of prisms for vision rehabilitation after macular function loss may impact oculomotor control. Canadian Journal of Ophthalmology. 2013;**48**:427-430

[69] Monés J, Gómez-Ulla F. Degeneración Macular asociada a la edad. Prous Science. 2005

[70] Bailie M, Wolffsohn JS, Stevenson M, Jackson AJ. Functional and perceived benefits of wearing coloured filters by patients with age-related macular degeneration. Clinical & Experimental Optometry. 2013;**96**:450-454

[71] Colombo L, Melardi E, Ferri P, Montesano G, Samir Attaalla S, Patelli F, et al. Visual function improvement using photochromic and selective blue-violet light filtering spectacle lenses in patients affected by retinal diseases. BMC Ophthalmology. 2017;**17**:149

[72] Tarita-Nistor L, Lam D, Brent MH, Steinbach MJ, González EG. Courier: A better font for reading with age-related macular degeneration. Canadian Journal of Ophthalmology. 2013;**48**:56-62

[73] Dodick D, Starling AJ, Wethe J, Pang Y, Messner LV, Smith C, et al. The effect of in-school saccadic training on reading fluency and comprehension in first and second grade students: A randomized controlled trial. Journal of Child Neurology. 2017;**32**:104-111

[74] Legge GE, Ahn SJ, Klitz TS, Luebker A. Psychophysics of reading—XVI. The visual span in normal and low vision. Vision Research. 1997;**37**:1999-2010

[75] Sunness JS, Schuchard RA, Shen N, Rubin GS, Dagnelie G, Haselwood DM. Landmark-driven fundus perimetry using the scanning laser ophthalmoscope. Investigative Ophthalmology & Visual Science. 1995;**36**:1863-1874

[76] MAIA. Centervue, Engineering Italian Creativity [Internet]. 2019. Available from: https://www.centervue.com/products/maia/ [2019/06/05]

[77] Rohrschneider K, Bültmann S, Springer C. Use of fundus perimetry (microperimetry) to quantify macular sensitivity. Progress in Retinal and Eye Research. 2008;**27**:536-548

[78] Kaltenegger K, Kuester S, Altpeter-Ott E, Eschweiler GW, Cordey A, Ivanov IV, et al. Effects of home reading training on reading and quality of life in AMD—A randomized and controlled study. Graefe's Archive for Clinical and Experimental Ophthalmology. 2019

[79] Hamade N, Hodge WG, Rakibuz-Zaman M, Malvankar-Mehta MS. The effects of low-vision rehabilitation on reading speed and depression in age-related macular degeneration: A meta-analysis. PLoS ONE. 2016;**11**

[80] Gill K, Mao A, Powell AM, Sheidow T. Digital reader vs print media: The role of digital technology in reading accuracy in age-related macular degeneration. Eye. 2013;**27**:639-643

[81] Morrice E, Johnson AP, Marinier JA, Wittich W. Assessment of the apple iPad as a low-vision reading aid. Eye. 2017;**31**:865-871

[82] Deemer AD, Swenor BK, Fujiwara K, Deremeik JT, Ross NC, Natale DM, et al. Preliminary evaluation of two digital image processing strategies for head-mounted magnification for low vision patients. Translational Vision Science & Technology. 2019;**8**:23

[83] Dunbar HMP, Dhawahir-Scala FE. A discussion of commercially available intra-ocular telescopic implants for patients with age-related macular degeneration. Ophthalmology and therapy. 2018;**7**:33-48

[84] Agarwal A, Lipshitz I, Jacob S, Lamba M, Tiwari R, Kumar DA, et al. Mirror telescopic intraocular lens for age-related macular degeneration. Journal of Cataract & Refractive Surgery. 2008;**34**:87-94

[85] Scharioth GB. New add-on intraocular lens for patients with age-related macular degeneration. Journal of Cataract and Refractive Surgery. 2015;**41**:1559-1563

[86] Boyer D, Freund KB, Levy MH, Garg S. Long-term (60-month) results for the implantable miniature telescope: Efficacy and safety outcomes stratified by age in patients with end-stage age-related macular degeneration. Clinical Ophthalmology. 2015;**9**:1099-1107

[87] Razavi H, Baglin E, Shatangan P, Caruso E, Tindill N, Griffin S, et al.

Gaming to improve vision: 21st century self-monitoring for patients with age-related macular degeneration. Clinical and Experimental Ophthalmology. 2018;**46**:480-484

[88] Ratra D, Rakshit A, Ratra V. Visual rehabilitation using video game stimulation for Stargardt disease. Therapeutic Advances in Ophthalmology. 2019;**11**:1-9