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Effects of oculomotor rehabilitation in children with visual and/or oculomotor dysfunction – A Systematic Review

Universidade Fernando Pessoa

Faculdade de Ciências da Saúde

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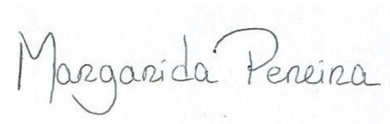

Margarida Valente Pereira (Assinatura)

Dissertação apresentada à Universidade Fernando Pessoa como parte dos requisitos para obtenção do grau de Mestre em Fisioterapia Materno-Infantil, sob orientação da Professora Doutora Olga Maria Barros Maia.

RESUMO

A visão é essencial para o desenvolvimento das crianças, facilitando as suas habilidades cognitivas, sociais e motoras, e é importante, em especial, para o seu sucesso escolar. A presente revisão sistemática teve como objetivo estudar os efeitos da reabilitação oculomotora nas funções da visão e dos anexos do olho, e nas sensações associadas aos mesmos. Como objetivo secundário, foram estudados os efeitos da reabilitação oculomotora nas funções mentais de crianças com disfunções oculares. A pesquisa foi realizada nas bases de dados PubMed, Web of Science, Psychology and Behavioral Sciences Collection, Academic Search Complete e Scholar Google. Todos os estudos incluídos foram ensaios clínicos randomizados, cuja qualidade metodológica foi avaliada através da Physiotherapy Evidenced Database (PEDro) Scale. Dos nove estudos incluídos na síntese qualitativa, as amostras diziam respeito a crianças com insuficiência de convergência, ambliopia, Transtorno do Défice de Atenção e Hiperatividade, disfunção oculomotora, baixa habilidade de leitura e/ou hipermetropia. Todos os estudos demonstraram associação positiva entre o programa de reabilitação oculomotora em teste e a melhoria dos parâmetros visuais, oculomotores e/ou mentais, em crianças entre os 5 e os 17 anos de idade. Apesar do número de ameaças que colocam em causa as inferências destes achados, os resultados clínicos gerais sugerem que os programas de reabilitação oculomotora têm efeitos positivos nas funções da visão e dos anexos do olho e sensações associadas, bem como na cognição, comportamento e habilidades de leitura de crianças com disfunção oculomotora. São necessárias investigações adicionais para confirmar a eficácia da terapia oculomotora e para escolher o melhor programa de intervenção para cada paciente, dependendo dos objetivos de intervenção e das suas características clínicas e pessoais.

Palavras-chave: Crianças; Disfunção; Mobilidade Ocular; Olho; Reabilitação Oculomotora; Visão.

ABSTRACT

Vision is essential to children development, facilitating cognitive, social and motor skills, and it is important, in particular, for school success. This systematic review aimed to study the effects of oculomotor rehabilitation on the functions of vision and structures adjoining the eye and on sensations associated, in children. As a secondary objective, the effects of oculomotor rehabilitation on the mental functions of children with ocular dysfunctions was studied. The research was conducted in PubMed, Web of Science, Psychology and Behavioral Sciences Collection, Academic Search Complete and Scholar Google databases. All the studies included were randomized controlled trials (RCT), which methodological quality was assessed with The Physiotherapy Evidence Database (PEDro) Scale. From the nine studies included in qualitative synthesis, the samples concerned children with convergence insufficiency, amblyopia, Attention Deficit Hyperactivity Disorder (ADHD), oculomotor dysfunction, poor reading skills, and/or hypermetropia. All of the studies demonstrated a positive association between the oculomotor rehabilitation program under test and improvement on visual, oculomotor and/or mental parameters, in children aged between 5 and 17 years old. Despite the number of threats that challenge the inferences of these findings, the overall clinical results suggest that oculomotor rehabilitation programs have positive effects on the functions of vision and structures adjoining the eye and sensations associated, as well as on cognition, behavior and reading skills of children with oculomotor dysfunction. Additional investigation is required to confirm the efficiency of oculomotor therapy and to choose the best intervention program to each patient, depending on the intervention objectives and their clinical and personal characteristics.

Keywords: Children; Dysfunction; Eye; Ocular Mobility; Oculomotor Rehabilitation. Vision.

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ADHD – Attention Deficit Hyperactivity Disorder

BEG – Bates Exercise Group

CANTAB – Cambridge Neuropsychological Test Automated Battery

CEG – Convergence Exercise Group

CG – Control Group

CPT-2 – Continuous Performance Task-2

CTG – Crowded Training Group

ELFE – Évaluation de la Lecture en FluencE

F – Female

ICF – International Classification of Functioning, Disability and Health

IED – Intra/Extradimensional Set Shift

IG – Intervention Group

IN – Infantile Nystagmus

JBI – Joanna Briggs Institute

KD Test – King Devick Pro Reading test

L2MA – Langage Oral Écrit Mémoire Attention

M – Male

NPC – Near Point of Convergence

NSUCO – Nova Southeastern University College of Optometry

OMEG – Oculomotor Exercise Group

OVT – Orthoptic Vergence Training

PEDro – The Physiotherapy Evidence Database

PedsQI – The Pediatric Quality of Life Inventory

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analysis

RCT – Randomized Controlled Trial

RVP – Rapid Visual Information Processing

SWM – Spatial Working Memory

TVMS – Test of Visual-Motor Skills-Revised

UTG – Uncrowded Training Group

VA – Visual Attentional

VNG – Videonystagmography

VOR – Vestibulo-Ocular Reflex

WISC-IV – Wechsler Intelligence Scale for Children

I – INTRODUCTION

Vision is the transformation of light into a nerve impulse that is processed in the brain. It depends as much on the eyes as it does on the brain. The eyes' main function is to detect patterns of light and then connect with the brain to convert them into images (Lens, Nemeth e Ledford, 2008; Pascual-Leone *et al.*, 2005; Remington e Goodwin, 2021).

Firstly, light enters through the cornea, which allows to see sharp and clear things, and then into the pupil. Through pupillary sphincter and pupillary dilator muscles, the iris regulates the pupil size and controls the amount of light that enters in the eye, with pupil dilation allowing more light to enter. Behind the iris is the lens, that when changes shape, focuses light on the retina. With the action of ciliary muscles, the lens thickens so that the eye focuses on nearby objects, and becomes thinner to focus on distant objects. Then, lens concentrates the light onto the retina, which contains two types of photoreceptors, the cones and the rods, and blood vessels that nourish it. Cones are responsible for precise, central, detailed and color vision and are mainly grouped in the macula, and rods are responsible for peripheral and night vision. The high density of cones in the macula generates a more detailed visual image. Rods are more numerous than cones and much more sensitive to light, and are clustered mainly in the peripheral areas of the retina. Each photoreceptor is connected to a nerve fiber. The nerve fibers of the photoreceptors group together to form the optic nerve. Retinal photoreceptors convert the image into electrical impulses, which are transmitted to the brain via the optic nerve. The two optic nerves meet at the optic chiasm where each of it splits, and half of the nerve fibers cross to the opposite side on its way to the posterior area of the brain. Thus, the right side of the brain receives information from the two optic nerves for the left field of vision, and the left side of the brain receives information from the two optic nerves for the right field of vision. The middle of these fields of vision overlap and is seen by both eyes, a process known as binocular vision. Each eye sees an object from a slightly different angle, so that information the brain receives from each eye is different, though it overlaps. The brain then combines the image of both eyes into just one to produce a complete picture, as well as processes movement, depth, and various colors, and connects vision with memory, allowing the recognition of familiar things (Lens, Nemeth e Ledford, 2008; Pascual-Leone *et al.*, 2005; Remington e Goodwin, 2021).

The primary visual cortex constitutes the first level of cortical processing of visual information, from where it is transmitted via two main pathways: a ventral pathway to the temporal lobe, responsible for stimulus identification, and a dorsal pathway to the parietal lobe, that control stimulus location. The corpus callosum allows communication between the two cerebral hemispheres and unifies the perception of objects by connecting the cortical areas that represent the two hemifields (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

The eyeball divides into two segments, each filled with fluid – the frontal/anterior section that extends from the interior of the cornea to the front surface of the lens an it is filled with the aqueous humor, that nourishes internal structures. In this turn, this segment is divided into two chambers – a frontal one, from the cornea to the iris and a posterior one, that extends from the iris to the lens. Normally, aqueous humor is produced in the posterior chamber, flows slowly through the pupil and into the anterior chamber, then exits the eyeball through exit channels located where the iris meets the cornea; the dorsal/posterior section extends from the posterior surface of the lens to the retina and it contains the vitreous humor (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

The primary visual cortex (named Brodmann's area 17) is responsible for the integration and perception of visual information. Association areas help to plan and execute complex motor activities (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

There are six extraocular muscles that move the eye: superior rectus, medial rectus, inferior rectus and inferior oblique (innervated by the oculomotor or common ocular motor, III cranial nerve), the superior oblique (innervated by the trochlear, IV cranial nerve), and the lateral rectus (innervated by the abducens, VI cranial nerve). The medial rectus adducts the eye (inward), the lateral rectus abducts the eye (outward), superior rectus is responsible for upward movement, inferior rectus for downward movement, inferior oblique moves the eye upward and outward and superior oblique moves downward and outward (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

There are several visual functions that support a variety of activities. Visual acuity is the ability to see details clearly, regardless of distance from the object. Color perception allows the differentiation of objects of similar size and shape. Stereopsis or binocular vision gives depth perception, allowing to assess distances and the speed of approaching objects. Contrast sensitivity refers to the ability to distinguish an object from its background, which can often involve distinguishing various shades of gray. Vision in the peripheral visual fields, as well as in the central part of it, helps the individual to move safely by detecting obstacles and movements in a person's side view (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

Visual acuity is essential for activities of daily living. The extraocular muscles enable the eyes to steer a direction in motion and help maintain the eyeball shape and its stability in the orbit, thus allowing a good visual acuity (Marieb e Hoehn, 2009).

Distance visual acuity is usually assessed using a vision chart at a fixed distance of 6 meters, usually Snellen Eye Chart created by the Dutch ophthalmologist Herman Snellen, in 1862 (Lindfield, 2014; Schneider, 2005, 2019; Tacca, Ferreira e Fagundes, 2019). The smallest line read on the graph is written as a fraction, where the numerator refers to the distance the graph is displayed and the denominator is the distance a healthy eye is able to read that line of vision graph. Normal vision is referred to as 6/6. Near visual acuity is measured according to the smallest print size a person can discern at a given test distance. In population surveys, near visual impairment is generally classified as a near visual acuity of less than 0.8 to 40 centimeters (Lindfield, 2014).

There are many neuronal circuits in the brain contributing to vision with different subfunctions. For effective processing of visual impulses in the brain and hence optimal visual performance, proper spatial networks and synchronization of all involved brain areas are required (Bola e Sabel, 2015; Uhlhaas e Singer, 2006).

While the eyes are at a certain fixation point, the brain must ensure the proper interaction of several subfunctions: sensory reception through the retina, uninterrupted transmission of visual impulses through the optic nerve to the brain, vigilance, motivation, attention to the task, retrieval of visual memory content and subsequent interpretation. Finally, coordination and execution of a motor response is required (eg. pressing a button or speaking). Each of these neuropsychological subfunctions requires its own circuitry and must be synchronized within a response time of 200–500 ms (Bola e Sabel, 2015; Sabel, 2017).

Some frequent ocular conditions occurring in children are strabismus, amblyopia, stereopsis, myopia, astigmatism and diplopia. Risk factors and causes of eye disease include aging, genetics, lifestyle behaviors, infections and other health problems. Most eye diseases are multifactorial (World Health Organization, 2019).

Strabismus is a condition in which the eyes are misaligned and it is associated with deficiency in the mechanism that integrates visual information from both eyes. It can be latent, if occurs occasionally, or manifest, if it’s constantly. The origin can be primary or can be caused by poor vision in one eye, refractive errors, lesions affecting the oculomotor, trochlear or abducens nerve and/or higher neurological pathways or it can also be caused by developmental or traumatic defects of the extraocular muscles (Friedman *et al.*, 2009; Hull *et al.*, 2017).

Strabismus is a risk factor for the development of amblyopia, the commonest vision disorder in children, during the first six to ten years of life (Friedman *et al.*, 2009; Hull *et al.*, 2017; Simons, 1996). Amblyopes have poor visual acuity, sensitivity and contour integration in one or both eyes (Friedman *et al.*, 2009; Hull *et al.*, 2017; Schmidt, Arnold e Miller, 2004). During childhood, neural plasticity is strongest, so clinical interventions are important in this stage of life (Friedman *et al.*, 2009; Hull *et al.*, 2017).

Also strabismus has a profound effect on stereopsis, which is the perception of depth produced by the brain's reception of visual stimuli originating in both eyes (Hull *et al.*, 2017). Stereopsis normally develops within the first three to four months of age and reaches adult levels at about three years of age (Braddick *et al.*, 1980; Fawcett, Wang e Birch, 2005; Petrig *et al.*, 1981; Robert *et al.*, 1980; Takai *et al.*, 2005). Both strabismus and reduced stereopsis adversely affects motor skills, particularly fine motor skills, social interactions and emotional wellbeing, which impacts on child neurodevelopment (Grant *et al.*, 2007; Hrisos *et al.*, 2006; O’Connor *et al.*, 2010; Webber *et al.*, 2008).

In myopia there is a lack of focus caused by a discrepancy between eye size and refractive power. In astigmatism there is an asymmetry of the radii of curvature of different corneal or crystalline meridians (Marieb e Hoehn, 2009; World Health Organization, 2019).

Injury to the right oculomotor (III) nerve causes paresis, when partial damage, or paralysis, if complete damage, of the medial, superior and inferior rectus and inferior oblique muscles, in addition to the pupillary sphincter muscle, resulting in mydriasis, and eyelid lift muscle, resulting in eyelid ptosis, on the right side. Thus, the function of these muscles is partially (muscle weakness) or totally compromised (no function), affecting ocular mobility and, consequently, vision (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021). Injury to the right trochlear (IV) nerve causes paralysis of the right superior oblique muscle. Finally, injury to the right abducens (VI) nerve causes paralysis of the right lateral rectus muscle. In all conditions, dipoplia usually appears and it gets worse when patient looks on the direction in which the paralyzed muscle would move the eye (Lens, Nemeth e Ledford, 2008; Remington e Goodwin, 2021).

In an era in which technology is present in our daily lives and society is increasingly connected to the digital world, several studies show that smart device exposure might be associated with an increased risk of myopia (Foreman *et al.*, 2021).

Some studies revealed that covid-19 pandemic has doubled cases of myopia among children between 6 and 8 years old worldwide. This comes as a warning to health professionals, educators and parents or caregivers about the need for collective efforts to prevent infantile myopia (Wang *et al.*, 2021; Zhang *et al.*, 2021). The trend is to worse, so it is very important to invest on prevention, early detection, treatment and rehabilitation (World Health Organization, 2019, 2019).

Also increased time spent indoors, with no natural light, and increased “near work” activities are leading to more people suffering from myopia. Increased outdoor time can reduce this risk (World Health Organization, 2019, 2019)

Children are not advised to have contact with screens before two years old. In addition, the absence of screens during meals is important and it is advisable to turn off all devices at least 1 hour before bed. While watching, it is recommended to take breaks at least every 30 minutes to look at another target. This allows the eye muscles to relax and focus on something far away, reducing internal eye pressure. The same is advisable, for example, when reading a book (Despotidis, Tannen e Lee, 2018).

Commonly, the manifestations of ocular dysfunctions are firstly noticed by members of the family, careers or educators, when they get too close to the television, cannot see the board, or start to squinting to see better (Hull et al., 2017). Thus, it is essential to educate the whole society about these alterations and possible solutions or required interventions.

Among children, vision impairment is associated with greater symptoms of depression and anxiety (Aa, Van Der *et al.*, 2015; Demmin e Silverstein, 2020; Parravano *et al.*, 2021; Virgili *et al.*, 2022). A systematic review from this present year has shown that surgical treatment of strabismus improved these symptoms (Li *et al.*, 2022), which means that the treatment of vision impairment, particularly strabismus is important not only for visual function but also for healthy mental functions. This could also be achieved through oculomotor rehabilitation, in cases where there is no need for surgery.

More than 1 billion people worldwide are living with vision impairment because they do not get the care they need for ocular problems like myopia, glaucoma and cataract, according to the first world report on vision issued by the World Health Organization. Rural areas, people with low income, women, the elderly, people with disabilities, ethnic minorities and indigenous populations are the most affected (World Health Organization, 2019, 2019).

According to the International Classification of Functioning, Disability and Health (ICF), “disability” is a general term used to describe a problem in the function or structure of an individual's body due to a health condition (WHO, DGS, 2004). This definition is compatible with the 11th Edition of International Classification of Diseases (WHO, 2021). Consequently, a visual impairment occurs when an eye disease affects the visual system and one or more of its visual functions.

Typically, population-based surveys measure visual impairment using visual acuity exclusively, with severity categorized as mild, moderate, or severe with respect to far and near vision impairment and blindness. However, in the clinical setting, other visual functions are also frequently assessed, such as visual field, contrast sensitivity and color vision (World Health Organization, 2019, 2019).

Eye conditions that can cause vision impairment are the main focus of prevention and treatment worldwide. Although, eye conditions that do not typically impair vision, including dry eye and conjunctivitis, must not be overlooked as they occur frequently at any age, including in childhood (World Health Organization, 2019, 2019). Stronger integration of eye care is needed within national health services, including at primary health care level (World Health Organization, 2019, 2019).

Although the retina and optic nerve do not regenerate, there is some potential for recovery of visual fields loss through neuroplasticity (Sabel, 2017). This refers to the ability of the brain to change its own functional architecture that can be induced by repetitively stimulating brain circuit, which is actually the neurobiological basis of learning (Pascual-Leone *et al.*, 2005). Brain analyses and interprets visual information and is able to activate and strengthen residual vision by enhancing synaptic efficacy. Because modulation of neuroplasticity can partially recover visual functions and more than half of the human cerebral cortex is involved in vision, the brain deserves a better reputation in ophthalmology for its role on visual rehabilitation (Sabel, 2017). Obviously, if the retina or optic nerve is completely damaged, visual recovery is impossible, but this doesn't happen in most of the patients and they still receive some information through these structures (Pascual-Leone *et al.*, 2005).

Synapses that are used more and more permanently strengthen their transmission conductivity through the release of neurotrophic factors (Zuccato e Cattaneo, 2009), involved in the growth, survival and differentiation of neurons, so that "practice makes perfect" (Sabel, 2017). The brain structure is made up of extremely dynamic and functional networks that can change in milliseconds depending on current needs. In ophthalmology, however, the concept of neuroplasticity is still not used in an integrative way, because the belief in an immutable and rigidly connected neural visual system still exists. Although in recent decades the neuroplasticity of the visual system has been increasingly known, implementation in practice still does not happen in most realities of health unities (Zuccato e Cattaneo, 2009).

Oculomotor rehabilitation is still little known and recognized, however, there is already research pointing to the positive effects of this approach both in treatment and prevention of oculomotor disorders in children, increasing their ocular function and quality of life (Gabriela Mendes Fontinele *et al.*, 2018; Jafarlou *et al.*, 2017; Tacca, Ferreira e Fagundes, 2019). As there are various specializations within physiotherapy, ocular physiotherapy focuses on eye motility and function, which is essential, however, to relate to the rest of the body.

Some treatment paradigms are vision restoration training, which is a behavioral task to selectively stimulate residual vision, and non-invasive alternating current stimulation, which activates and synchronizes the entire retina with brain (Kasten, Wuest e Sabel, 1998; Sabel, 2017). Though full restoration of vision is not possible, such treatments improve vision about 70% of the patients, including visual field enlargements, better acuity, reaction time and quality of life, through local activation of the visual cortex and reorganization of neuronal brain networks (Sabel, 2017).

Vision is essential for reading, which is a key aspect of the development and learning on school-age children (Gibbs, Appleton e Appleton, 2007). Reading involves quick and specific ocular movements of fixation from one to another point called saccades, which allow a clear image and an internal representation of the visual environment (Blais *et al.*, 2009). Saccades must be acquired and improved over time during childhood and are primarily controlled by the frontal cortex, which programs the exact direction and distance through which the eye must move (Bilbao e Piñero, 2020; Blais *et al.*, 2009; Zhao *et al.*, 2012). These movements take about 200 to 250 milliseconds. Saccadic eye movements and perceptual attention work in a coordinated way to allow objects, features or regions selection with the greatest momentary need for visual processing resources and their connections are crucial for visual tasks. Pre-saccadic attention affects both memory selection and visual representations. The main role of spatial attention is to facilitate active saccadic vision (Knudson e Morrison, 2002; Zhao *et al.*, 2012). Attention may operate without saccades, but the opposite don't happen (Bilbao e Piñero, 2020; Zhao *et al.*, 2012). There are two types of saccadic tasks, prosaccadic ones, that require participants to make a saccade, as quickly as possible, to the location of an sudden onset peripheral target, whereas an antisaccade task requires to make it on the opposite direction, but of the same distance of the abrupt onset target (Pratt e Trottier, 2005).

In the other hand, occipital cortex gives commands for the visual pursuit movements, whose speed can reach 45 degrees per second, and trajectory and direction vary according to the relative movement of the object. Visual pursuit skill is used to keep the object of interest in focus, when the object or subject moves, one in relation to the other (Bilbao e Piñero, 2020; Knudson e Morrison, 2002; Zhao *et al.*, 2012).

Eye movements can then be initiated and controlled by different neural subsystems, depending on the visual task involved and on origin, voluntary or reflex. In all of them, the proper processing of visual information requires a minimum image stability that is projected on the retina. Among reflexes that are intended to maintain the stability, optokinetic and vestibulo-ocular reflexes are the most important (Bilbao e Piñero, 2020; Zhao *et al.*, 2012). The optokinetic reflex includes a steady eye movement on the direction at which the object or scene is moving to stabilize the image on the retina. It depends from visual system. The vestibulo-ocular reflex, by activation from the vestibular system, acts to stabilize gaze during head movement, through eye movement production into the opposite side (Bilbao e Piñero, 2020; Zhao *et al.*, 2012). Otolith organs (saccule and utricle) are important vestibular structures, located in the inner ear, essential for these reflexes and responsible for detecting static position and linear head movements. Semicircular canals detect angular head movements. Thus, the vestibular system plays an important role on visual function and balance (Bilbao e Piñero, 2020; Zhao *et al.*, 2012).

Ocular fixation is a dynamic process controlled by many of the same brain structures involved in eye movements, including cerebellum, superior colliculus and reticular formation (Krauzlis, Goffart e Hafed, 2017). Visual fixation denotes to the ability to carefully watch an object with visual attention and appropriate focus (Knudson e Morrison, 2002).

Learning disorders are usually detected when children begin to read and most of them have simultaneously visual symptoms related to ocular motility, especially saccades, accommodation and/or binocular vision (Jainta e Kapoula, 2011; Pensiero *et al.*, 2013).

Dyslexia is a neurobiological learning disorder that affects about 5% of school-age children (Gori e Facoetti, 2015). It involves difficulty in reading, producing and understanding written language, and it can affects also auditory memory, speech, naming or finding words process. It is thought to result from congenital neurodevelopmental abnormalities that affect the left ‘brain hemisphere areas responsible for language association, sound and speech production, the interconnections between these areas, or a combination. It does not affect intelligence and usually there is reading difficulty (Bosch-Bayard *et al.*, 2018). It is more prevalent in boys (Gori and Facoetti, 2015).

There are several studies reporting vestibular dysfunction and oculomotor abnormalities in the most of dyslexic children (Ciuffreda *et al.*, 2006; Shaywitz *et al.*, 1999; Siok *et al.*, 2009). The etiology of these oculomotor abnormalities may be the result of oculomotor pathways immaturity (Jafarlou *et al.*, 2020). In addition, cerebellar function is also suspected to be impaired in dyslexic patients. The cerebellum plays an important role in stabilizing vision, by predicting image movement during ocular movements, and in receiving information from the vestibular and visual systems (Démonet, Taylor e Chaix, 2004). Many studies found a relationship between impairment of the vestibular system and cognition (Furman *et al.*, 2012; Hitier, Besnard e Smith, 2014; Semenov *et al.*, 2016; Smith *et al.*, 2005). It is well known that there are connections between the inner ear and the brainstem, limbic system and hippocampus, which indicates the deep connection of the vestibular system with cognitive processes, such as memory and attention. Therefore, any vestibular dysfunction can affect, in addition to balance and visual function, cognitive functions such as attention and spatial memory (Guidetti, 2013; Hanes e McCollum, 2006; Marcelli *et al.*, 2009; Smith *et al.*, 2005).

Improvement of cognitive performance following vestibular rehabilitation in subjects with vestibular disorders has been shown in several studies, suggesting cognitive-vestibular interaction (Hanes e McCollum, 2006; Hitier, Besnard e Smith, 2014; Redfern *et al.*, 2004; Schautzer *et al.*, 2003).

ADHD is another neurobiological learning disorder often associated with visual changes and learning and social interaction difficulties (Bauchner, 2000; Bilbao e Piñero, 2020).

Reading difficulties are present in individuals with any of these two learning disorders mentioned, but the role of visual dysfunction on the development of these difficulties and, consequently, on the generation of learning problems, remains controversial. Control of eye movements and accuracy in saccades promote a much more effective reading skill, copying, distance calculation and road crossing but do not necessarily imply a simple causal relationship between oculomotor problems and learning disorders (Bilbao e Piñero, 2020; Farrell, 2011; Nazir e Nabeel, 2019).

The term oculomotor is related to eye movement control and it is one of the parts of visual system that can be easily trained. The defect or absence of purposeful, precise and voluntary eye movements leads to oculomotor dysfunction (Nazir e Nabeel, 2019).

Oculomotor dysfunction ordinary symptoms include ocular discomfort, eyestrain, reading the same content repeatedly, weak reading comprehension, avoidance or reluctance for reading, rub the eyes while reading and tendency to fall asleep and the use of finger for reading most of the times, which is a developmentally behavior that may vanish with oculomotor improvement skills as the child gets older (Nazir e Nabeel, 2019).

Oculomotor dysfunction is one of the main causes of low reading ability among children, where there is usually loss of ocular fixation and saccade ability. Slow eye movements lead to reduced reading speed by the child. Learning to read is a complicated phenomenon that involves visual processing and oculomotor functions. The eyes must be able to concentrate (form saccades) and focus (fixations) letter by letter, word by word and line by line. Eye tracking exercises and eye training can improve a child's visual efficiency and allow them to perform effective visual fixation while reading, increasing their concentration. Visual tracking involves three types of visual skills: fixation, saccade, and pursuit, which are the core of visual system (Nazir e Nabeel, 2019). Oculomotor training improves eye movements control and general reading ability (Thiagarajan *et al.*, 2014).

Fischer e Hartnegg, 2009, showed successful training of visual fixation and saccadic skills on improvement reading ability of dyslexic children. Regarding older people, Rosengarth *et al.*, 2013 noted positive effect of oculomotor training on fixation stability, visual acuity and reading speed.

Guzman-Martinez *et al.*, 2009, noted that training through informed visual flicker enhanced the eye fixation ability and it also reduced the amplitude and quantity of saccades. Knudson e Morrison, 2002, found that oculomotor control and reading speed among adult readers improved when provided the training of home based computerized visual saccade. Also Knudson e Morrison, 2002, offered eye movement exercises in addition to eye-hand coordination to participants with developmental coordination disorder, which improved their vertical visual pursuit ability (Knudson e Morrison, 2002).

Some studies (Brodney e Kehoe, 2001; Brodney, Kehoe e Sinha, 2010) with students from the 1st to the 4th year of elementary school have shown improvements on the oculomotor performance of students with visual problems through implementation of a computerized visual therapy program. These improvements were reflected in eye tracking and reading abilities, duration of eye fixation, in both vertical and horizontal eye movements, and accommodative facility (Brodney e Kehoe, 2001; Brodney, Kehoe e Sinha, 2010), in contrary to what happened with adults in Knudson e Morrison, 2002, what suggests that results are better in small aged individuals.

Eye fixation and saccadic visual skills are essential for the correct functioning of the normal eye tracking system. Good readers express better ocular performance based on duration of visual fixation, duration of visual saccades, and number of visual regressions (Nazir e Nabeel, 2019; Powers, Grisham e Riles, 2008).

Meir Schneider was a man born in 1954 with many visual conditions such as strabismus, glaucoma, astigmatism, nystagmus and cataracts, who underwent several unsuccessful surgical procedures, and then began to execute visual exercises every day for hours, according to the Bates method (Schneider, 2005, 2019). Surprising everyone, after a year of this routine, he improved his ocular functionality (Schneider, 2005, 2019). Today, he has a functional vision and don’t need to use glasses (Schneider, 2005, 2019). With his own experience, he defends that the body is capable of self-healing, what led him to develop the Self-Healing Method, through improvement of the primitive exercises created by Bates (Schneider, 2005, 2019). He created the School for Self-Healing to teach about the method, which integrates visual and body exercises to enhance visual function, which may cause changes in myopia and astigmatism (Schneider, 2005, 2019).

The study by Dr. Bates was innactive for about 100 years, as he probably went through problems related to medicine, facing difficulties in this sector to take advantage of the techniques (Tacca, Ferreira e Fagundes, 2019).

One study of Tacca, Ferreira e Fagundes, 2019, used exercises based on Self-Healing Method (Schneider, 2005, 2019). It was performed, sequentially, body relaxation exercises, blood circulation stimuli, muscle stretching (head, cervical, and upper limbs), ocular exercises with relaxation of the eye region, stretching with eye movements, expansion of peripheral and central vision through varied visual stimuli and global body relaxation. For a better understanding of this protocol treatment, an illustrated explanatory leaflet was developed, containing the proposed exercises (**Annex 1**). This study was carried out with people aged between 25 and 60 years old (Tacca, Ferreira e Fagundes, 2019). All participants in this study reported acquiring “knowledge for the rest of their lives” and that they were unaware, until that moment, about the care they should have with their eyes, as well as the exercises they should do. Also, all five participants become able to carry out their daily activities without wearing glasses at least good part of the day (Tacca, Ferreira e Fagundes, 2019). The participants' distance visual acuity improved an average of 39.4% in both eyes according to the reading of a line in the Snellen chart (Schneider, 2005, 2019; Tacca, Ferreira e Fagundes, 2019).

It appears to exist a few knowledge among the majority of the population that Physiotherapy can act on visual function and collaborate with visual treatment (Schneider, 2005, 2019).

Schneider and other authors defend that eye training is needed for prevention of ocular dysfunctions just as physical therapy is needed for the rest of the body. Visual exercises reduce eye fatigue and pain by moistening the eyes, reducing tension on the muscles around the eyes and reduces ocular inflammation or itching (Schneider, 2005, 2019; Tacca, Ferreira e Fagundes, 2019).

A study carried out with individuals aged between 8 and 60 years have result in improvement of symptoms, such as difficulty focusing the text, lack of concentration, burning eyes, diplopia and consequent headache. This study included stretching exercises for the medial rectus muscle, isometric strengthening of the lateral rectus muscles, exercises for divergence, Brock's rope exercises, divergence ruler and Hart's tables. The protocol consisted of six physiotherapy sessions, twice a week (Wolff e Taglietti, 2019). Another study also showed the effectiveness of oculomotor rehabilitation in convergence insufficiency in individuals aged around 20 years (Kmetzki e Taglietti, 2019).

The Self-Healing Method created by Meir Schneider produces an increase on visual function, on reducing ocular pain or discomfort and on well-being. By paying attention to peripheral vision, it can be reduced the effort of central vision, thus obtaining more clarity from the objects. Stimulation of peripheral vision in relation to the environment, eye coordination exercises and relaxation of central vision allow the improvement of visual function. If on the one hand, the glasses constitute a protection for the eyes, on the other hand, Meir Schneider defends that the more people wear glasses or contact lenses, the more they become dependent on them, as they do not give their eyes the opportunity to train and recover natural strength and capacity. Nevertheless, the definitive removal of glasses should only occur after authorization from an ophthalmologist (Schneider, 2005, 2019; Tacca, Ferreira e Fagundes, 2019).

The Method has proven to be effective, however, it is still not widely applied. A restructuring in ophthalmology and inclusion of this method is essential to more effective and satisfactory results for the patients, including allowing a reduction on treatment duration. It should be clarified, in the medical community, that it is not intended to replace treatments, but to complement the existing ones with the techniques presented in literature (Tacca, Ferreira e Fagundes, 2019).

Another study carried out with university professors (Menigite e Taglietti, 2017) showed that the practice of eye exercises becomes important for visual health, as they improve the performance of the eye muscles, avoid headaches, reduce visual stress, promote a better concentration and relax the eye muscles. In addition, they are beneficial on a variety of ocular diseases, such as myopia, strabismus, nystagmus, presbyopia and convergence insufficiency (Menigite e Taglietti, 2017).

Non-invasive, alternating current, vision restoration training improves vision in about 70% of cases without serious adverse events (Sabel, 2017).

Currently, there is an attempt to give recognition to ocular physiotherapy as the role of the physiotherapist in extrinsic ocular motility. The ocular physiotherapist must evaluate and diagnose an ocular deviation, through appropriate techniques, identify which paralyzed or paretic extrinsic ocular muscle(s), guide and supervise the treatment through exercises and approaches capable of improving eye function and also performing pre- and post-operative assessments capable of assisting the ophthalmologist in surgical treatment (Gabriela Mendes Fontinele *et al.*, 2018).

A systematic review published in 2020 suggests that there is a pattern of oculomotor anomalies in children with learning disorders (Bilbao e Piñero, 2020). Thus, it becomes important to study the effect of oculomotor rehabilitation also on the mental functions of this patients.

According to the International Classification of Functioning, Disability and Health, Children & Youth Version, elaborated by the World Health Organization (World Health Organization, 2007) seeing functions are sensory functions relating to sensing the presence of light and sensing the form, size, shape and color of the visual stimuli, which includes visual acuity functions, visual field functions, quality of vision, functions of sensing light and color, visual acuity of distant and near vision, monocular and binocular vision, visual picture quality, impairments such as myopia, hypermetropia, astigmatism, hemianopia, colour-blindness, tunnel vision, central and peripheral scotoma, diplopia, night blindness and impaired adaptability to light. Functions of structures adjoining the eye are the functions of structures in and around the eye that facilitate seeing functions and include functions of internal muscles of the eye, eyelid, external muscles of the eye, including voluntary and tracking movements and fixation of the eye, lachrymal glands, accommodation, pupillary reflex, impairments such as in nystagmus, xerophthalmia and ptosis. Lastly, sensations associated with the eye and adjoining structures are sensations of tired, dry and itching eye and related feelings, such as the ones descripted by pressure behind the eye, something in the eye, eye strain, eye burning and eye irritation (World Health Organization, 2007).

The topic that was chosen for investigation, in the present systematic review, was about oculomotor rehabilitation, because it is simultaneously a personal area of interest of the author and also a current subject on expansion, about which there are already some primary experimental studies, however, few secondary studies, such as systematic reviews. Thus, it was carried out a brief search on the literature in order to deepen the mentioned issue and verify the existing studies, as well as their results. Although motor, cognitive and auditive neuroplasticity are already widely used in rehabilitation, then it is important to apply it to the visual system as well, particularly in pediatrics.

In this context, it was determined as primary objectives of this systematic review to study the effects of oculomotor rehabilitation on the functions of vision and structures adjoining the eye and on sensations associated with the eyes and structures adjoining the eye, in children. As a secondary objective, the effects of oculomotor rehabilitation on the mental functions of children with ocular dysfunctions will be studied.

II – METHODS

2.1 Design

This systematic literature review was conducted between March and July of 2022 about the effects of oculomotor rehabilitation in children with visual and/or oculomotor dysfunction. It is reported as per Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher *et al.*, 2015).

2.2 Data sources and literature search strategy

Five databases were searched from June to July 2022: PubMed, Web of Science, Psychology and Behavioral Sciences Collection, Academic Search Complete and Scholar Google. The overall search strategy was developed by two independent researchers.

The PICO question formulated for this present investigation was "Is oculomotor rehabilitation an effective type of intervention in visual and/or oculomotor impairment of children, regarding their functions of vision and structures adjoining the eye and sensations associated, as well as mental functions?", where "P" (Population), "I" (Intervention) and "O" (Outcome) are, respectively, children, oculomotor rehabilitation and functions of vision and structures adjoining the eye, sensations associated and mental functions. No "C" (Comparison intervention) was stablished.

The search terms used were: oculomotor AND (rehabilitation OR exercises OR reeducation OR program) AND (child OR children OR infant). The fields that were defined for keyword research were "All Fields" in Pubmed and "Topic" with selection of "All databases" in Web of Science. No search filters were selected in Psychology and Behavioral Sciences Collection or Academic Search Complete databases. In Scholar Google only the first 300 results were analyzed. Any time restriction was not imposed regarding the publication date of the articles.

A secondary search was conducted in the list of references of the included articles to identify other possible relevant studies.

2.3 Inclusion and exclusion criteria

The studies were eligible for inclusion if: (i) were randomized controlled trials (RCT) or case-control studies, ii) included oculomotor rehabilitation as the main subject, iii) participants were children with visual dysfunction, dysfunction of the structures adjoining the eye and/or with sensations associated with the eyes and structures adjoining the eye; iv) were published in Portuguese, Spanish, French, Italian and/or English.

Studies were excluded based on the following criteria: (i) the main subject was not an oculomotor rehabilitation program; ii) participants were children with neurological pathology, with the exception of ADHD and dyslexia; iii) children with a previous clinical history of traumatic brain injury and/or neurological events; iv) children simultaneously participating in other rehabilitation and/or exercise program; v) written in another language than Portuguese, Spanish, French, Italian or English; vi) inaccessible.

2.4 Study selection

Two independent reviewers assessed all remaining titles and abstracts and judged each article for eligibility. If this was insufficient for determining eligibility, then the fulltext articles were retrieved. Full-text articles were obtained from the remaining eligible abstracts. One reviewer independently screened the references lists of all included articles for any additional relevant studies. During each review phase, regular meetings were held to discuss criteria. Discussion and consensus resolved disagreements among reviewers.

2.5 Methodological quality assessment

The methodological quality of included studies was evaluated by two independent reviewers. PEDro scale was chosen to evaluate the quality of randomized controlled trials (Costa, 2011) and Checklist for Case Control Studies from Joanna Briggs Institute (JBI) to evaluate case-control studies (Martin, 2017) possible to include.

The JBI Checklist for Case Control Studies classifies each item on “Yes”, “No”, “Unclear” or “Not applicable”, while PEDro scale only classifies on “Yes” or “No”. Also PEDro scale consists of eleven items of evaluation, while JBI scale include ten items. Lastly, PEDro Scale establishes a final score ranging from 0 to 10 points, with the maximum contribution of one point by each item to the total score, except from the first item. A score between 6 and 10 is indicative of high methodological quality, between 4 and 5 means a satisfactory quality and less than or equal to 3 reveals poor quality (Maher *et al.*, 2003; Morton, de, 2009). The scale from JBI don’t settle a final score, but the greater the number of "yes", the better is the methodological quality of the study.

Divergencies between researchers were discussed until consensus were reached, with a third assessor being involved if needed.

III – RESULTS

3.1 Study selection

Figure 1 represents the flow chart of literature research, based on the recommendations and structure of PRISMA. Initial research revealed 1163 results, which corresponded to 833 different studies after removing the duplicates. Inaccessible studies, studies from a foreign language or with a wrong type of publication were removed, as well as studies that did not meet our objectives or did not study our population of interest, information that could be obtained from the abstracts. From the 57 studies remaining, only 9 studies met the eligibility criteria and were therefore included in the current systematic review.

3.2 Methodological quality

All the nine included studies were RCT, therefore every one of the studies was scored with PEDro scale concerning to its methodology. The final score varied between 1 and 9 points, with four studies (Caldani *et al.*, 2020; Janmohammadi *et al.*, 2019; Nazir e Nabeel, 2019; Scheiman *et al.*, 2005) having high quality, three (Bayram, Karagöz e Algun, 2020; Jafarlou *et al.*, 2020; Wiener-Vacher *et al.*, 2019) were satisfactory and two of them (Huurneman, Boonstra e Goossens, 2016; Jafarlou *et al.*, 2017) had poor quality.

All studies had well-defined eligibility criteria (maximum score on item 1). The criteria that failed the most was that the physical therapists had administered the therapy blindly, in which only one study (Wiener-Vacher *et al.*, 2019) ensured that this criterion was met. Eight of the nine studies showed measures of precision, such as measures of variability, for at least one key outcome, having accomplished the item 11 of PEDro.

Results of methodological quality assessment of each one of the studies are presented in

3.3 Inclusion and exclusion criteria of the studies

All the studies established the eligibility criteria, which were very variable among them. All met the inclusion and exclusion criteria previously defined for this systematic review. Four studies established as exclusion criteria, vestibular and psychiatric pathology (Bayram, Karagöz e Algun, 2020; Caldani *et al.*, 2020; Huurneman, Boonstra e Goossens, 2016; Nazir e Nabeel, 2019).

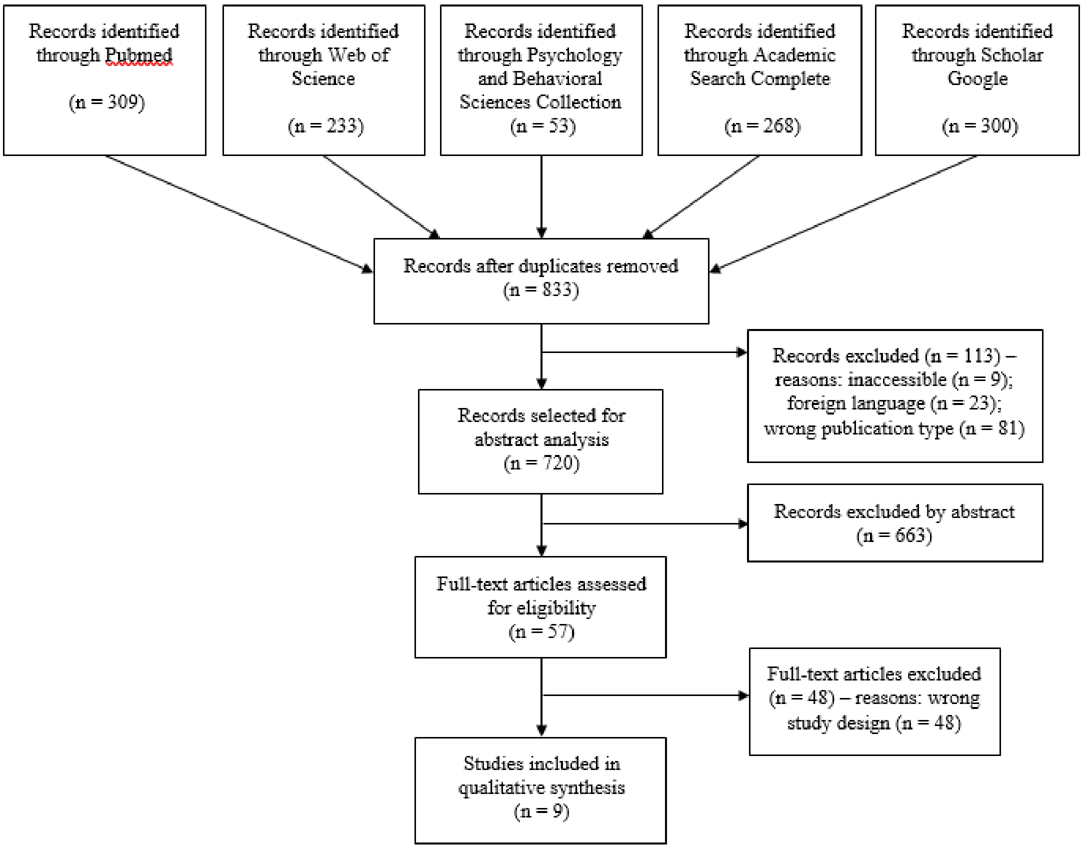

Figure 1. Flow chart of literature research.

Table 1. Metodological quality evaluation of the studies included, with PEDro Scale.

Study / **Item**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Final score from PEDro Scale**
(Wiener-Vacher et al., 2019)	1	0	0	0	0	1	0	0	1	1	1	**4**
(Scheiman et al., 2005)	1	1	1	1	0	0	0	1	1	1	1	**7**
(Janmohammadi *et al.*, 2019)	1	1	1	1	1	0	1	1	1	1	1	**9**
(Nazir e Nabeel, 2019)	1	1	1	1	0	0	0	1	1	1	1	**7**
(Jafarlou *et al.*, 2020)	1	1	0	0	0	0	1	1	0	1	1	**5**
(Bayram, Karagöz e Algun, 2020)	1	0	0	0	1	0	1	1	0	1	1	**5**
(Jafarlou *et al.*, 2017)	1	1	0	0	0	0	0	0	0	0	0	**1**
(Huurneman, Boonstra e Goossens, 2016)	1	0	0	0	0	0	0	1	0	1	1	**3**
(Caldani *et al.*, 2020)	1	1	0	1	1	0	0	1	1	1	1	**7**

3.4 Study design, sample and characteristics of the CG and IG

All studies are RCT and included a control group (CG) in their investigation to make comparisons. Although Bayram, Karagöz e Algun, 2020, have not specified directly the existence of any CG, it can be concluded through this study analysis that the BEG (conventional treatment) group refers to the CG. Four studies (Huurneman, Boonstra e Goossens, 2016; Jafarlou *et al.*, 2017, 2020; Wiener-Vacher *et al.*, 2019) included a CG of healthy children and from these studies, only in Wiener-Vacher *et al.*, 2019 the CG have received the same treatment of the intervention group (IG). In the other three studies healthy children have received no intervention.

Eight studies included a CG of participants similar to those of the IG regarding diagnosis and the indicators of the more important prognosis, however, these CG have received an intervention program different from the IG, which was an alternative intervention from the one that the authors wanted to study.

Two studies included one CG and two IG (Bayram, Karagöz e Algun, 2020; Huurneman, Boonstra e Goossens, 2016), two studies used exactly the same sample, which included one IG and two CG (Jafarlou *et al.*, 2017, 2020) and Scheiman *et al.*, 2005, included two IG and two CG. The others studies included only one CG and one IG.

The sample of all different studies has included only children, but it was quite variable regarding health conditions. The samples concerned children with convergence insufficiency and consequent dizziness (Wiener-Vacher *et al.*, 2019), amblyopia (Scheiman *et al.*, 2005), ADHD (Janmohammadi *et al.*, 2019), oculomotor dysfunction and/or poor reading skills (Huurneman, Boonstra e Goossens, 2016; Nazir e Nabeel, 2019), dyslexic children with oculomotor abnormalities (Jafarlou *et al.*, 2017, 2020) or children with hypermetropia (Bayram, Karagöz e Algun, 2020).

In general, the sample size of the studies was small, which ranged from 39 to 507 participants. Janmohammadi *et al.*, 2019, reported results only for boys, rather than for combined groups of both sexes, as the others studies. All the studies presented the number of individuals by gender, except Caldani *et al.*, 2020, and Huurneman, Boonstra e Goossens, 2016. In general, the age of the children ranged between 5 and 17 years old.

In Bayram, Karagöz e Algun, 2020, the distribution of subjects by group was done in order of arrival at the study site, which is not a reliable method of randomization.

Bayram, Karagöz e Algun, 2020, Caldani *et al.*, 2020, and Janmohammadi *et al.*, 2019, were the only studies that guaranteed that children were unaware of the experimental interventions, and only their parents were informed about the goal of the study.

More details about results of the studies are presented in **Table 2**.

3.5 Intervention Protocols

In three of the nine studies (Bayram, Karagöz e Algun, 2020; Nazir e Nabeel, 2019; Wiener-Vacher *et al.*, 2019), the intervention program lasted 6 weeks. In addition, two studies (Huurneman, Boonstra e Goossens, 2016; Janmohammadi *et al.*, 2019) applied a 5-week program and the other two (Jafarlou *et al.*, 2017, 2020) applied an 8-week training program. The longest intervention program corresponded to 24 weeks, and only one (Caldani *et al.*, 2020) put into practice a very short training, of only 10 minutes, a single day. Regarding training frequency and follow-up, in five studies (Huurneman, Boonstra e Goossens, 2016; Jafarlou *et al.*, 2017, 2020; Janmohammadi *et al.*, 2019; Wiener-Vacher *et al.*, 2019) the program on testing was performed twice a week and three of the studies (Bayram, Karagöz e Algun, 2020; Nazir e Nabeel, 2019; Scheiman *et al.*, 2005) involved daily exercise.

All studies investigated an oculomotor rehabilitation program, where two of them had the objective of comparing the effects of two (Huurneman, Boonstra e Goossens, 2016) or three (Bayram, Karagöz e Algun, 2020) different programs among each other, in the sense of knowing which one was the most beneficial for the sample in question.

Only Jafarlou *et al.*, 2020 specified that children in the CG received the same oculomotor rehabilitation program of IG, after completion of the study, as an ethical consideration.

In general, eye movement exercises included saccades, tracking or visual fixation simultaneously with divergence or convergence, or still directional and circumduction eye movements. The exercises were manual (with mazes, word finds, and other eye-hand activities) and/or computer animated (with *GameBoy*, for example).

Table 2. Goals, population, protocol, measures and results of the studies included.

Female (F); Male (M).

(Author, year)	Goals	Population	Protocol	Measures	Results
(Wiener-Vacher et al., 2019)	To test short- and long-term efficacy of orthoptic vergence training (OVT) and instructions to reduce screen usage, in children with dizziness and vergence disorders.	IG: 49 children with convergence insufficiency and consequent dizziness 9-13 years old 25 M, 24 F CG: 109 healthy children 6-17 years old boy/girl ratio = 0.98	12 sessions of OVT, twice a week. Patients performed the same exercises during each session: ocular saccades and pursuits at near distance, and divergence and convergence at both far and near distances, using several instruments such as Berens prism bar, synoptophore and stereograms. The patients were firstly encouraged to make efforts to increase vergence amplitudes and reach normal values, during the exercises, and then they repeated all exercises to make the responses automatic and effortless. Patients and their families were also encouraged to reduce videoscreen exposure daily.	Patients were evaluated before OVT (M0), 3 months after the end of OVT (M3) and 9 months after the end of OVT (M9). Children from both groups had classic orthoptic evaluation (measure of near point of convergence (NPC); *eye covered-uncovered test*; measurement of the fusion amplitude for divergence and convergence using a *Berens* prism bar; measurement of the stereoscopic depth discrimination using the TNO) and oculomotor evaluation through video binocular movement recordings (velocity vs. latency) with the *Mobile EyeBrain Tracker* (Mobile EBT, SuriCog) at a recording frequency of 300 Hz and 0.25 precision, during various saccadic, convergent and/or divergent tasks. An increase in speed and a decrease	At M0, all orthoptic and oculomotor parameters were statistically different between IG and CG ($p<0.0001$), except for divergence amplitude. Latencies were significantly longer and velocities significantly lower in IG than in CG for all oculomotor conditions, at M0. At M3, vertigo symptoms from IG had disappeared, and all oculomotor parameters improved (increased speed and decreased latency time of movements) significantly ($p<0.0001$) in IG, except for velocities of saccade alone, combined saccades with divergence and convergence. These gains of IG were not significantly different from CG, except for near saccades and combined saccades with convergence. Regarding orthoptic evaluation at M3, the NPC values from IG improved statistically and significantly relative to M0 and were not significantly different from CG. Amplitudes of near and far convergence improved significantly in IG at M3 and M9 and these values were greater than CG. Divergence amplitudes were not significantly different in

				in latency time of movements translates into improvements in oculomotor parameters.	patients of IG relative to controls at M0, M3, and M9. From M3 to M9, all orthoptic and oculomotor parameters of IG continued to improve significantly (near and far saccade gains increased and latencies of near saccades decreased) or remained stable, without significant differences when compared to CG.
(Scheiman et al., 2005)	To evaluate the effectiveness of treatment of amblyopia in children aged 7 to 17 years.	507 patients with amblyopia, ranging from 20/40 to 20/400 10-17 years old Patients 7-12 years: <u>IG</u>: n=201 89 F, 44 M <u>CG</u>: n=203 87 F, 44 M Patients 13-17 years: <u>IG</u>: n=55 31 F, 56 M <u>CG</u>: n=48 25 F, 52 M	At a screening visit prior to randomization, a new pair of spectacles was provided for all patients regardless of whether a change was needed <u>IG</u>: optical correction + amblyopia treatment, which included 2-6 hours per day of prescribed patching of the sound eye, combined with 1 drop daily of 1% atropine sulfate for the sound eye and near visual activities for at least 1 hour a day while patching: GameBoy – Nintendo, Redmond or Wash; homework, reading, computer work, and the use of workbooks designed for the study with mazes, word	Participants were evaluated regarding: i) visual acuity in each eye wearing optimal optical correction (electronic *Early Treatment Diabetic Retinopathy Study* testing procedure); ii) binocularity (*Titmus test* and the *Randot Preschool Stereoacuity Test;* iii) ocular alignment with a simultaneous *prism and cover test* at distance and near fixation (modified *Krimsky test* used if fixation poor); iv) cycloplegic refraction (using 1% cyclopentolate hydrochloride, performed with retinoscopy, subjective refraction, or both); v) ocular examination including pupillary dilation; vi) eccentric fixation with a direct ophthalmoscope; vii) occurrence and frequency of symptoms of diplopia.	In the IG, among the 201 patients in the younger group, 2 hours of patching per day were prescribed for 101 patients (50%), 4 hours for 82 patients (41%), and 6 hours for 18 patients (9%) and atropine was prescribed for all but 1 patient. Glasses for near work were prescribed for 46 (23%) of these patients. Among the 55 patients in the older group assigned to IG, 2 hours of patching per day were prescribed for 34 patients (62%), 4 hours for 19 patients (35%), and 6 hours for 2 patients (4%). In the 7- to 12-year-olds (n=404), 53% of IG were responders compared with 25% of the CG (P<0.001). younger age was associated with greater improvement. In the 13- to 17- year-olds (n=103), the responder rates were 25% and 23% for IG and CG, respectively, (adjusted P=0.22).

			finds, and other eye-hand activities. CG: optical correction only	Follow-up occurred every 6 weeks. Follow-up in both groups was discontinued when nonresponder criteria were met: any visual acuity improvement from baseline at 6th week visit or less than 3-letter or than 5 letter, at the 12th week and 18th week, respectively Patients whose amblyopic eye acuity improved 10 or more letters (at least 2 lines) by 6th, 12th, 18th or 24th week were considered responders.	
(Janmohammadi *et al.*, 2019)	To investigate eye movement practices and their inhibitory role in behavioral function in children with ADHD	39 boys with ADHD 6-10 years old IG: n=20 7.05±0.8 years CG: n=19 7.37±1.01 years	IG: occupational therapy accompanied with eye-tracking exercises. CG: only occupational therapy Ocupational therapy intervention included a perceptual-motor programme and pediatric massage therapy in both IG and CG. Eye-tracking program was running for 5 weeks, 2 sessions per week, 30 min per session, with progression of the exercises. The subjects were individually treated and and it was used a	Patients were evaluated using the *Conner's Parent Rating Scale*, *Wechsler Intelligence Scale for Children* (WISC-IV) the *Continuous Performance Task-2 (*CPT-2*)*, and the *Test of Visual-Motor Skills-Revised* (TVMS), before and after the intervention.	Significant improvements in the posttest in cognitive scores (F=9/22), coping behavior (F=6.03) and hyperactivity (F=9.77) were detected between IG and CG (p<0.05), which indicate that eye movement intervention skills caused cognitive problems, coping behavior and hyperactivity in children with ADHD significantly improved at post-test. Furthermore, in the *CPT-2* scores, detectability (F=5.68), omission errors (F=17.89), commission errors (F=19.45), reaction time (F=8.95), variability (F=7.07), and preservation (F=6.33) showed significant differences between IG and CG (p<0.01), which supports that component of the visual patterns in IG significantly improved performance at post- test.

			format (play) for the training to increase motivation.		The results of covariance analysis on the effects of education on improving the visual patterns of TVMS showed a significant difference between IG and CG (p<0.001), evidencing that teaching visual patterns improve visual motor skills and was significantly effective in boys with ADHD.
(Nazir e Nabeel, 2019)	To determine the effect of an fixation skills training on the improvement of these skills and of the reading fluency in children with oculomotor dysfunction.	20 children with oculomotor dysfunction and poor reading skills 5-14 years old, at primary level school <u>IG</u>: n=10 <u>CG</u>: n=10	<u>IG</u>: training of manual (5 exercises) and computer animated (2 exercises) visual fixation skills, 50 minutes per day, 7 days a week, for 6 weeks (42 sessions) <u>CG</u>: no intervention.	Participants were evaluated before and after the intervention, regarding: i) oculomotor dysfunction (*King Devick Pro Reading test* (KD Test); ii) lvel of visual fixation skills (numbers and time of duration of visual fixations during reading, evaluated with the help of *Visagraph II* instrument and recorded videos); iii) level of visual saccadic and pursuit skills (*Nova Southeastern University College of Optometry* (NSUCO) *Oculomotor Test*); iv) reading fluency (determination of *Words Correct Per Minute* (WCPM) *Method*, using selected paragraphs of *Punjab Textbook Board*). The level of saccadic and pursuit skills was only measured before intervention.	There was significant effect (p=0.003) of the training of visual fixation skills on the reading fluency of children with oculomotor dysfunction. The level of reading fluency of IG was significantly better (65 WCPM) than CG (57 WCPM). A highly significant improvement (p=0.001) in the eye fixation skills of IG was found through visual fixation exercises training, than CG.
(Jafarlou *et al.*, 2020)	To evaluate the effects of oculomotor	30 dyslexic children with	<u>IG</u>: oculomotor rehabilitation, which was performed for 1 hour, twice weekly, for 8	Oculomotor subtype of videonystagmography (VNG)	There were significant differences between healthy and dyslexic children in all oculomotor tests. In the saccade test, in dyslexic children

	rehabilitation on the cognitive performance of dyslexic children.	oculomotor abnormalities 24 M, 6 F 8-12 years old <u>IG</u>: n=15 11 M, 4 F 8-12 years old <u>CG</u>: 25 children; 13 M, 2 F 8-12 years old The 30 dyslexic were compared to 20 healthy children: 14 M, 6 F 8-12 years old	weeks. It included accommodative exercises with focus on saccade, tracking and fixation exercises. <u>CG</u>: no intervention.	testing including gaze, saccade, tracking, and optokinetic tests were used for evaluation of central vestibular pathways and recording of eye movements. Three cognitive subtests of *Cambridge Neuropsychological Test Automated Battery* (CANTAB), a computerized neurological test battery – *Intra/Extradimensional Set Shift* (IED), *Rapid Visual Information Processing* (RVP) and *Spatial Working Memory* (SWM) –, were performed pre and post-intervention stage to determine the effects of intervention on the cognitive function (attention and spatial memory).	compared to normal children, latency and velocity of saccades were increased and accuracy was decreased, indicated hypermetric eye movements in dyslexic children. Both IED total errors, RVP mean latency scores and SWM total errors of IG in the posttest reduced significantly compared to pre-test scores in this group (p = 0.001), whereas these parameters of the CG did not change on the posttest. The correct scores of all cognitive tests in the IG posttest increased significantly compared to the CG (p = 0.028), which indicates a positive effects of oculomotor rehabilitation on the cognitive performance of dyslexic children.
(Bayram, Karagöz e Algun, 2020)	To investigate the effect of different eye exercises on hypermetropia in school-aged children and whether exercise protocols have	60 hypermetropia school-aged children 7-17 years old <u>Bates Exercise Group (BEG)</u>: n=20 11 M (55%)	All the programs were practiced at home and had 6-week duration. Exercise booklets covering exercise protocols and exercise diaries were given to the participants. Also, once a week, it was made reminder phone calls to all patients. <u>BEG</u>: a protocol involving 4-directional and circumduction	Participants were evaluated before and after 6-weeks programs, regarding: 1) visual acuity (*Snellen* chart); 2) hypermetropia (sciascopy); 3) health related quality of life (*The Pediatric Quality of Life Inventory* (PedsQI) Version 4.0.).	In BEG, no statistical difference was seen in visual acuity, sciascopy and PedsQL measures (p>0.05). CEG showed a statistically significant effect on visual acuity for the right and left eye (p=0.004, p=0.014, respectively) and PedsQI (p<0.05). In the OMEG, there was a statistically significant effect on visual acuity for the left eye (p=0.011), and in sciascopy and PedsQI (p<0.05).

	superiority to each other.	Convergence Exercise Group (CEG): n=20 8 M (40%) Oculomotor Exercise Group (OMEG): n=20 11 M (55%)	eye movements, a set 10 repetitions, twice a day. CEG: a convergence exercise protocol at home for 5 minutes, in the morning and in the evening. OMEG: 4 oculomotor exercises with gaze stabilization, 10 repetitions of each, twice a day.		In the comparison between the groups, it was determined that oculomotor exercises contributed the most to the visual acuity of the left eye (p = 0.006).
(Jafarlou *et al.*, 2017)	To measure oculomotor parameters and analyze the effect of oculomotor rehabilitation strategies on dyslexia.	30 dyslexic children with oculomotor abnormalities 24 M, 6 F 8-12 years old IG: n=15 11 M, 4 F 8-12 years old CG: 25 children; 13 M, 2 F 8-12 years old The 30 dyslexic were compared, relative to oculomotor functions, to 20 typical readers children:	IG: Oculomotor rehabilitation, which was performed for 1 hour, twice weekly, for 8 weeks. It included accommodative exercises with focus on saccade, tracking and fixation exercises. A brochure of the same exercises was designed for the parents and was taught to them and to the children to continue rehabilitation exercises at home, in addition to clinic exercises. Parents were told that homework had to be done 3 times a day for 15 minutes each time. CG: no intervention.	Eye movements were evaluated through four oculomotor tests, pre and pos-intervention: gaze, tracking, saccade and optokinetic tests. It was also applied spontaneous nystagmus test. Binocular eye movements were recorded by oculomotor subtype of videonystagmography (VNG) testing (*Interacoustics VO425-2D-VOGfw model*), using a binocular infrared goggle. Both dyslexic and non-dyslexic children were evaluated.	There were significant differences in oculomotor characteristics of dyslexic children in comparison with those reported in typical children. There was significant difference between pre and posttest for all oculomotor variables ($p<0.001$) in IG, except for optokinetic gain ($p= 0.501$) and saccade velocity ($p= 0.161$). There was no significant difference among oculomotor variables, and the values of all variables were almost the same in CG ($p>0.05$). There were no significant differences between IG and CG in any of oculomotor variables before the intervention ($p>0.05$). After the intervention, a significant difference was observed between IG and CG groups in all oculomotor variables ($p<0.001$), except for optokinetic gain ($p= 0.591$). Oculomotor rehabilitation intervention had a positive effect on improvement of oculomotor responses and eye movements in dyslexic children, except for optokinetic response.

		14 M, 6 F 8-12 years old			
(Huurneman, Boonstra e Goossens, 2016)	To determine changes in oculomotor behavior after a perceptual learning program on a letter discrimination task in children with infantile nystagmus (IN).	36 children with IN (18 children with idiopathic IN and 18 with oculocutaneous albinism accompanied by IN), aged 6 to 11, years were divided into 2 training groups matched on diagnosis: Uncrowded training group (UTG): n=18 Crowded training group (CTG): n=18 CG: 11 age-matched children with normal vision	Participants first performed the fixation and saccade task, then the single-letter and crowded-letter task, and finally the reading task. UTG: Work with *single Landolt-Cs* CTG: A crowded letter task, where target size and target-to-flanker spacing were gradually reduced as the child's performance improved. Each training session consisted of 7 blocks of 50 trials. Training occurred twice per week for 5 consecutive weeks (3500 trials total). CG: no intervention.	Participants were evaluated relative to several eye movements, which were recorded in two dimensions with an eye tracking system (*EyeLink 1000 Plusregarding*): 1) monocular and binocular distance visual acuity (*uncrowded and crowded version of the Landolt C-test*); 2) near vision binocularly (*crowded and uncrowded LH version of the C-test*); 3) nystagmus characteristics (amplitude, frequency, intensity, and the expanded nystagmus acuity function); 4) fixation stability (the bivariate contour ellipse area and foveation time); 5) saccadic eye movements (latencies and accuracy), made during a simple saccade task and during a crowded letter-identification task. Children with IN were measured within 2 weeks before and after training. Children with normal vision were measured twice with a 7- to 10-day interval. At retest, they only	Saccadic responses of children with IN improved on the saccade task (latencies decreased by 14 ± 4 ms and saccade gains increased by 0.03 ± 0.01), but not on the crowded letter task. There were also no training-induced changes in nystagmus characteristics and fixation stability. Although children with normal vision had shorter latencies in the saccade task (47 ± 14 ms at baseline), test-retest changes in their saccade gains and latencies were almost equal to the training effects observed in children with IN.

				performed the saccade and letter discrimination tasks.	
(Caldani *et al.*, 2020)	To explore whether a short visual attentional training could improve reading capabilities in children with reading disorders by changing their oculomotor characteristics.	50 children with reading disorders, divided into 2 groups 7.8 - 12 years old IG: n=25 9.56 $\pm$ 0.29 CG: n=25 9.74 $\pm$ 0.38	IG: 10 min of visual attentional rehabilitation: oculomotor exercises (horizontal visually-guided saccades and horizontal pursuits during 2 min, presented on the PC that was used for the reading task) without recording eye movements and 3 searching tasks ("house", "cat" and "space rockets", during 5-7 min by using *Metrisquare© Lebe Business Centers Sittard* CG: No intervention – they spoke for about 10 min with the 2 examiners. The child was invited to read aloud one text during 1 min.	Eye movements during the reading task were recorded (using an *Eye Brain T2®* head-mounted eye tracker) twice, both for IG and CG, i.e., before (T1) and after (T2) 10 min-intervention. The text was presented on a 22-inch LCD. Participants were evaluated regarding: 1) text comprehension and the ability to read words and pseudowords (*Langage Oral Écrit Mémoire Attention* (L2MA)); 2) the reading age (*Évaluation de la Lecture en FluencE* (*ELFE test*) and the *visual attentional (VA) span test*);	At T1, oculomotor performances during reading (*ELFE test* and *VA span test)* were statistically similar for both groups of children with reading disabilities (IG and CG). At T2, the IG only improved oculomotor capabilities significantly during reading; in particular, children read faster and their fixation time was shortest (p<0.0001).

Others interventions used either in isolation on the CG, or as a complement to the main treatment of the IG, were optical correction, patching of the sound eye, drop daily of 1% atropine sulfate for the sound eye, occupational therapy (perceptual-motor program and pediatric massage therapy) or just talking with the examiners, without any other approach.

Two studies demanded a reading task (Caldani *et al.*, 2020; Huurneman, Boonstra e Goossens, 2016), in which one distinguished a single from a crowded-letter task (Huurneman, Boonstra e Goossens, 2016).

Only one of the studies (Scheiman *et al.*, 2005) consisted only of home-based exercises, in which, once a week, it was made reminder phone calls to all patients to follow-up. With respect to home strategies, it was provided exercise booklets with exercise protocols, exercise diaries (Bayram, Karagöz e Algun, 2020; Jafarlou *et al.*, 2017) or encouragement to the children and their families to reduce screen usage (Wiener-Vacher *et al.*, 2019). At a visit prior to beginning of the protocol training, a new pair of spectacles was provided for all children, regardless of whether a change was needed, in Scheiman *et al.*, 2005. In all of them, children with prescription glasses wore them during both measurements and training sessions.

Janmohammadi *et al.*, 2019, reported the concern in using a play format for the training to increase children' motivation. In one of the studies (Wiener-Vacher *et al.*, 2019) the participants performed the same exactly exercises every sessions, without progression, unlike the others one. In studies involving video recording of eye movements, children were seated in front of the monitor with their head supported by a head- and chinrest to prevent head movements and so, data alteration.

Janmohammadi *et al.*, 2019 did not mention whether the CG and IG programs had the same duration.

3.6 Measured Parameters and Evaluation Tools

Concerning oculomotor assessment, six studies (Caldani *et al.*, 2020; Huurneman, Boonstra e Goossens, 2016; Jafarlou *et al.*, 2017, 2020; Nazir e Nabeel, 2019; Wiener-Vacher *et al.*, 2019) had video recorded binocular eye movements from the participants, with infrared goggle and a specific software. However, all chosen software were different between each other. Different oculomotor tasks were asked for during this recording, such as fixation, tracking and/or saccade movements, optokinetic tests, and/or nystagmus tests. The parameters analyzed were velocity, latency and/or accuracy of the eye movements, numbers, time of duration, ellipse area and/or foveation time of visual fixations, amplitude, frequency, intensity and/or acuity of nystagmus.

In two studies (Bayram, Karagöz e Algun, 2020; Scheiman *et al.*, 2005) binocularity was assessed with manual visual tools or without recording. Also only two studies (Scheiman *et al.*, 2005; Wiener-Vacher *et al.*, 2019) assessed ocular alignment, to determine if a patient had either a phoria or a tropia, both using a simultaneous prism fusion range and a cover test.

Regarding other functions rather than oculomotor or visual ones, only one study (Janmohammadi *et al.*, 2019) included clinical tools for obtaining behavior, intelligence and sustained and selective attention skills, other one (Jafarlou *et al.*, 2020) assessed cognition, health related quality of life (Bayram, Karagöz e Algun, 2020) and two studies (Caldani *et al.*, 2020; Nazir e Nabeel, 2019) have checked for reading fluency of the children, although with different instruments.

In assessment and intervention contexts, the responsible and present professionals, who performed assessment, supervision and/or follow-up of the children, varied between orthoptics, optometrist, psychiatrist, psychologist and a therapist. Only (Bayram, Karagöz e Algun, 2020) referred that it was a physical therapist who administered the therapy and Janmohammadi *et al.*, 2019, referred to be the therapist, not specifying from which area of intervention.

Jafarlou *et al.*, 2017, 2020, Janmohammadi *et al.*, 2019, and Nazir e Nabeel, 2019, did not mention exactly how many time after the end of intervention program were the evaluations repeated.

3.7 Effects of oculomotor rehabilitation programs

Orthoptic treatment and advice to reduce screen usage had a significant and long term effect on vertigo symptoms as well as on oculomotor functions, in children with convergence insufficiency (Wiener-Vacher *et al.*, 2019).

Scheiman *et al.*, 2005, found that optical correction improved visual acuity by 10 or more letters in about one fourth of patients aged between 7 and 17 years old, however, additional patching combined with near activities and the take of atropine for the sound eye doubled the responder rate in children between 7 and 12 years old. This response to treatment was seen regardless of severity or origin of amblyopia in the patients, and whether the amblyopia had been or had not been previously treated. On the other hand, with regard to patients aged between 13 and 17 years, the analysis did not demonstrate a benefit on prescribing patching with near activities over optical correction alone. Despite of the positive results, most patients were left with a residual visual acuity deficit (Scheiman *et al.*, 2005).

According to the study of Janmohammadi *et al.*, 2019, it appears that eye-tracking interventions with neck and eye movement isolations have an important role in refining cognitive function and coping behaviors in children with ADHD. In this study, exercises based on the inhibitory control of eye movements during a stop-signal task, stopping performance, repeated task-switching, inhibition and error detection and regulation of countermanding saccades increased eye movement control, cognitive skills and response inhibition (Janmohammadi *et al.*, 2019).

The study of Nazir e Nabeel, 2019, showed that an eye fixation training can be helpful in improving both the impaired ocular skills as well as reading abilities, in children with oculomotor dysfunction (Nazir e Nabeel, 2019).

Jafarlou *et al.*, 2017, showed positive effects of oculomotor rehabilitation on eye movements, recommending that early oculomotor assessment as well early practice of an oculomotor intervention protocol, are highly recommended in dyslexic children. The study published three years later by the same authors, with the same sample, methodological strategies and where it was applied the same intervention protocol plus a booklet with home exercises and encouragement to the participants and their families, showed positive effects of this oculomotor rehabilitation program also on the cognitive performance of dyslexic children (Jafarlou *et al.*, 2020).

In another study, eye exercises, especially convergence and oculomotor exercises, were reliably performed for treatment of hypermetropia in school-aged children (Bayram, Karagöz e Algun, 2020).

In the study of Huurneman, Boonstra e Goossens, 2016, the results suggested that the improvement in visual performance after implementation of a perceptual learning training on a letter discrimination task, in children with IN, occured primarily due an increase in sensory processing rather than in improvement of oculomotor performance. The protocol training did not bring changes in nystagmus characteristics or fixational ocular movements of the children (Huurneman, Boonstra e Goossens, 2016).

Lastly, Caldani *et al.*, 2020, revealed that a short visual attentional training can improve the cortical mechanisms responsible for attention, speed up reading ability and decrease the duration of fixations during reading. It should be noted, however, that such visual attentional training did not lead to any change concerning prosaccades movements performance and regressions (Caldani *et al.*, 2020).

IV – DISCUSSION

Vision, the most dominant of human senses, plays a critical role in all facets and phases of life. People take vision for granted, but without vision, communicating, learning to walking, reading, attending school or working become harder (Heine e Browning, 2002).

Visual impairment occurs when an eye disease affects the visual system and one or more visual functions. A person who wears glasses or contact lenses to compensate for their visual impairment has still a visual disorder. Timely access to quality care, in particular to oculomotor rehabilitation programs, has a major influence on the impact of eye diseases (World Health Organization, 2019).

By analyzing the quality of the studies with PEDro, it can be concluded that only three of the studies included (Bayram, Karagöz e Algun, 2020; Caldani *et al.*, 2020; Janmohammadi *et al.*, 2019) managed to control the performance bias of the participants as well as three studies (Bayram, Karagöz e Algun, 2020; Jafarlou *et al.*, 2020; Janmohammadi *et al.*, 2019) ensured the blindness of the evaluators, nevertheless, only one study (Wiener-Vacher *et al.*, 2019) controlled the performance bias by the professional who performed or supervised the treatment program. This can result in differences in the care received by the IG and CG, with a possible influence of the investigator's expectations on the results.

In the study of Wiener-Vacher *et al.*, 2019, the initial exposure to small video screens and TV by the participants was about 3.6 hours per day, which was intensive and, probably, the advice given to reduce this habits had a propitious impact on maintaining or improving the long term results of OVT. Since intensive number of hours on the screen is, more and more, and increasingly at earlier ages, a global reality, all the studies should have also included advice in this regard.

In Scheiman *et al.*, 2005, it was very difficult to assess compliance from the participants, since they carried out the program without investigators supervision. Only about half of the participants returned the calendar of the treatments performed at home, as asked at the beginning of the study, and beyond that it cannot be ensured the credibility of these records. Also in this study, patching of the sound eye was prescribed to be between 2 and 6 hours a day (Wiener-Vacher *et al.*, 2019), which, on the one hand, is a big interval and it can cause great variability on the intensity of the treatment performed among children, influencing the final results. On the other hand, it is well known that, depending on the clinical condition of each patient and their personal characteristics, the need for treatment time, to achieve the same results, changes from person to person.

According to the results of Janmohammadi *et al.*, 2019, eye-movement based programs leads to decreasing and inhibition of unwanted saccades and to improvements on cognitive function and behavior of children with ADHD. Considering the relationship among the prefrontal cortex, which is implicated on planning complex cognitive, decision making and/or social behavior as well as on visual perception, the oculomotor system and response inhibition, it seems that oculomotor rehabilitation may reduce hyperactivity in children with ADHD, as ocular tasks involve similar brain regions. Unfortunately, it was not used, during this research, an eye tracker to analyse eye movement patterns with precision (Janmohammadi *et al.*, 2019).

The study of Nazir e Nabeel, 2019, presents a great contribution to professionals in Education field, in particular teachers, for the implementation of a rehabilitation plan, in classroom, involving gaze fixation exercises to improve reading fluency of children with oculomotor dysfunction.

Jafarlou *et al.*, 2020, points to the importance of the early diagnosis of oculomotor disorders in dyslexic children, essential to offer to these children a specific and suitable rehabilitation planning to each of them.

In the study Bayram, Karagöz e Algun, 2020, the improvement in visual acuity of the OMEG was due to the effectiveness of head movements in the oculomotor exercises on stimulating the vestibular system and, consequently, the vestibule-ocular reflex. This reflex acts to stabilize gaze during head movement, indispensable to normal visual acuity.

The results, still in Bayram, Karagöz e Algun, 2020, were bigger in the left eye than in the right one, nevertheless, it must be taken into account that left eye baseline hypermetropia values were higher than those in the right eye. Therefore, this result may suggest that the eye with bigger refractive error is more responsive to oculomotor rehabilitation (Bayram, Karagöz e Algun, 2020). Also, results of this study showed that the eye training performed contributed to a better quality of life of the children with hypermetropia and that the effect of oculomotor exercises on visual acuity was found to be higher than the other two approaches (Bayram, Karagöz e Algun, 2020). The computerized method used to visual acuity evaluation minimized the possibility of performance bias by evaluators and by IG (Bayram, Karagöz e Algun, 2020).

In study of Jafarlou *et al.*, 2017, for ethical reasons, booklets of oculomotor rehabilitation exercises were delivered to parents and dyslexic children in the CG, after completion of the study, to invite them do the exercises at home. The same it should be done in Jafarlou *et al.*, 2017, and Caldani *et al.*, 2020.

The studies Jafarlou *et al.*, 2020, and Jafarlou *et al.*, 2017, shared the same four authors, except one that participated only in this last mentioned study. Also, the 2017 study have only used videonystagmography as the assessment instrument, while the 2020 research added CANTAB. Regarding methodological quality, the 2020 study guaranteed a much higher quality, according to PEDro scale, compared to the other one. So, the 2020 research probably emerged to upgrade the previous one, namely to better understand the relationship between visual attention and oculomotor deficits in dyslexic children.

In Huurneman, Boonstra e Goossens, 2016, test-retest effects in children with normal vision were very similar comparing to therapy effects in children with IN, indicating that the improvement on saccade accuracy and latency found in IG were probably not due to improved oculomotor control, but rather a consequence of familiarization with the task. This study suggests that enhanced visual attention and/or sensory neuroplasticity are much more likely to explain the positive effects of a perceptual learning program on a better visual performance, than oculomotor skills (Huurneman, Boonstra e Goossens, 2016).

The findings from Caldani *et al.*, 2020, suggested that a short visual attentional program therapy can act efficiently on the neural network responsible for the ocular movement control mechanisms, such as duration of visual fixation, while reading, since that attention and eye movements are linked. The more knowledge about the role of attention abilities in dyslexic children is deepened, in the future, the more possibility there will be to improve their reading capabilities (Caldani *et al.*, 2020). A limiting important factor needed be taken in account is that the level of motivation of children of the CG was probably inferior comparing to IG, because CG received no intervention, only 10-minutes talk (Caldani *et al.*, 2020). The same it must be concluded in the other studies where the CG was not subjected to any treatment.

The fact that the ocular mobility assessment method was not always the same led to differences or heterogeneity among studies results. In future studies, as defended by Bilbao e Piñero, 2020, the normative values for each different parameter of visual and oculomotor skills evaluation must be presented, and the golden standard test or, when not possible, the reference standard test should be used, to better compare the results of investigations. Bilbao e Piñero, 2020, also suggest video-oculography as the reference standard test to evaluate oculomotor skills in children with learning disorders.

Several studies already indicate an association between cognition, reading speed and eye tracking ability. A primary study of Brodney, Kehoe e Sinha, 2010, conducted an investigation with students from 1st to 4th grade of elementary school, who underwent computerized visual therapy for 20 weeks, twice a week, at school. This visual therapy protocol showed significant improvements in ocular mobility, fixation and on reading ability of children with oculomotor dysfunction (Brodney, Kehoe e Sinha, 2010).

Fischer e Hartnegg, 2009, found that training of visual fixation and saccade can help to control the deficits in saccadic ability of a dyslexic child, therefore improving their reading ability. The success rate of the visual tracking training was found in 85% of participants of this study. A training program of dynamic tasks testing vision was utilized to improve reflexive saccade, antisaccade and visual fixation systems. The intervention was given individually to each dyslexic child, keeping in view their eye movement results during antisaccade task with gap conditions and prosaccade task with overlap conditions. A gadget namely *Fix Train* was provided for visual tracking at home (Fischer e Hartnegg, 2009).

A limitation present in all included studies was the small sample size, therefore, it is suggested future studies recruiting more participants. In addition, long-term follow-up was performed only in Scheiman *et al.*, 2005, what limits the investigation of long-term effects of oculomotor rehabilitation.

In the most of the studies studying dyslexic children, it was not used a reading test to diagnose dyslexia and they were not categorized based on severity of the condition. Also, several studies did not compare the IG with an healthy group.

All primary studies included in the present systematic review should have evaluated the effects or impact of oculomotor rehabilitation on child's neurodevelopment. A systematic review of this present year (Li *et al.*, 2022) showed that surgical correction of children with esotropia, a type of strabismus, leads to improvement in child general development.

Further studies should also analyze the impact of oculomotor rehabilitation on anxiety and depression of children with oculomotor dysfunction, once children with learning disorders and strabismus may have significantly greater conduct and externalizing problems (Chai *et al.*, 2009; Koklanis, Abel e Aroni, 2006; Li *et al.*, 2022).

V – CONCLUSION

Despite the number of threats that challenge the inferences of these findings, the overall results suggest that oculomotor rehabilitation programs have positive effects on the functions of vision and structures adjoining the eye and sensations associated, as well as on cognition, behavior and reading skills of children with oculomotor dysfunction.

It would have been better to have found more studies with the eligibility criteria, initially defined, fulfilled, feeling that there is still a lot to investigate with regard to oculomotor rehabilitation and the data collected in this present systematic review are just the beginning of an expanding, enriching area for children and adults with visual and/or oculomotor problems, in order to increase their functionality and quality of life.

The conclusions of this systematic review should be conveyed to kindergarten and general teachers to train them in the early identification and monitoring of children's oculomotor skills, as they spend most of their time in schools. It is essential that a rehabilitation plan be drawn up by a physical therapist, together with the child and the caregivers, to improve his/her eye movements and, consequently, the reading fluency, attention and cognition skills of these patients. Teachers themselves can help students on improving their reading skills, making adaptations to their teaching methodology, so that they are not constantly straining their eyesight, and may even include eye mobility exercises or visual hygiene strategies in their classes.

Research into the effects of oculomotor rehabilitation on children with visual impairments can and must continue. It is essential to link the fields of ophthalmology, neurology, physiotherapy and other health areas, in order to develop effective and individualized therapeutic approaches.

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ANNEXES

Annex 1. Exercises adapted from Meir Schneider's Self-Healing Method. Developed by the authors: (Tacca, Ferreira e Fagundes, 2019).