# Vision Training as a Treatment Option for Accommodative Dysfunctions

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**ABSTRACT**

This paper is a literature review of existing bibliography on the subject of accommodative dysfunctions and their methods of treatment, focusing more on vision training. The current study reviewed more than one hundred scientific articles, of which forty-four were included in the bibliography, with the goal to prove that vision therapy is a legitimate form of treatment for accommodative dysfunctions. The way the accommodative system functions and its possible dysfunctions are analyzed and researched in order to investigate the hypothesis. This literature review shows the effectiveness of vision therapy as a treatment method for accommodative dysfunctions. Frequently, in fact, it is indicated as the primary method of treatment, outweighing other options.

## INTRODUCTION

It is unarguable that vision is our primary sense. The integration of vision with other brain systems and pathways demonstrates how severely impaired we are without an effective visual system when trying to interpret our surroundings (Gates, 2011).

A well-functioning accommodative system plays a critical role in a person's everyday life and can influence their habits, their preferences and their whole way of functioning daily. An individual with any kind of accommodative dysfunction can encounter serious hardships and discomfort in their daily lives and their work, which will persist as long as the dysfunction is not treated. The term "accommodative dysfunction" is used to outline the difficulties that a person might encounter when their eyes are unable to focus properly (American optometric association). Some of the indications of such a dysfunction can be redness, tearing or eye itching, lack of focus, intermittent blur, avoiding close work tasks, confusion when changing vision from near to far and vice versa, headaches, fatigue and sleepiness.

Accommodation is the adjustment of the optics of the eye to keep an object in focus on the retina as its distance from the eye varies. It is the process of adjusting the focal length of the lens in order to see clearly when the object of interest changes distance from far to near and vice versa. It is usually developed in the first months of life and under normal circumstances it should work adeptly until around the age of 40, when presbyopia frequently appears. The largest possible increase in optical power that an eye can obtain when shifting its focus is known as the amplitude of accommodation.

The mechanisms used during accommodation involve the ciliary muscle, the lens and the pupil. The ciliary muscle is located in the middle of the eye and is attached to the lens by zonular fibers. It is responsible for the adjustment of the lens's shape and when it contracts, the lens becomes more spherical and increases its focusing power, in order to see clearly at a certain distance. The pupil constricts in pursuance of the reduction of the amount of light that enters the eye, and therefore the increase of the focal depth. At the same time, when we are looking at an object in a near distance, our eyes converge to shift our focus to the point of interest. This process is called accommodative reflex, it is activated by our sympathetic system and it contributes to the reduction of spherical aberrations, by reducing the amount of light reaching the retina. The system typically overaccommodates at a distance and underaccommodates at a close distance, causing a lag of accommodation. Accommodation is not at its resting condition at infinity, but rather at an intermediate distance that varies from person to person and falls between 0.75 and 1.50 diopters (D). The accommodation assessed in night myopia or empty field myopia is comparable to the resting state (Campbell, 1953; Knoll, 1952).

In young individuals with a healthy visual system, this process happens automatically, it is rapid and performed unconsciously when looking at objects at different distances. However, this is not the case when an accommodative dysfunction is present. Dysfunctions of accommodation usually develop in childhood but they can be diagnosed at any age. People that spend prolonged periods reading, studying or using a computer, are more likely to perceive and report the related symptoms, and therefore are more likely to be diagnosed early in life (Rosenfield, 2011; Ciuffreda, 2002).

The purpose of this paper is to conduct a thorough and extensive research and review of the current literature available regarding accommodative dysfunctions and the effectiveness of vision training

as a treatment method in adults and children with accommodative dysfunctions. The present literature research aims to provide an overview of current knowledge and identify relevant theories and methods.

## OBJECTIVES

The present research aims to investigate the effectiveness of vision therapy as a form of treatment for patients with accommodative dysfunctions. The aim of this literature review is to assess and explain the effect that accommodative training has on vision and on the optometric values that are involved in the diagnosis of an accommodative dysfunction. Through the apposition and the comparison of the results of the different relevant studies, a clear picture of this effect is drawn.

## METHOD

In the present literature review, a systematic and thorough literature research has been conducted using Google Scholar, Pubmed, Science Direct, OEP foundation website- Journal of Behavioural optometry and Europe PMC. The following keywords were used: vision therapy for accommodative dysfunctions, vision training, orthoptics, accommodative insufficiency, accommodative infacility, accommodative spasm, accommodative dysfunctions prevalence, accommodative excess, treatment (all fields), accommodative amplitude, accommodative facility, accommodative spasm.

All articles were carefully examined and in order to find additional publications that are crucial to the review, the reference lists of all relevant articles were inspected. The inclusion criteria consisted of research published in English or Greek which examined accommodative dysfunctions, their prevalence, diagnosis, symptoms, epidemiology and methods of treatment. All relevant studies from 1950 up to this day were included as there were no exclusion criteria regarding to the date of issue. Fifty-four articles were included in total, while the amount of the sources that were studied was over one hundred.

## RESULTS

A decrease in accommodation can be physiological (presbyopia), pharmacological (cycloplegia) or pathological (accommodative insufficiency, accommodative infacility). A decrease in accommodation due to accommodative insufficiency or infacility does not have to be permanent and can be treated without the use of surgical means, whereas presbyopia is permanent and in cycloplegia the effect is temporary. When there is a surplus of accommodation there may either exist an accommodative excess or an accommodative spasm. Another case of an accommodative dysfunction is ill-sustained accommodation, where the patient has a normal accommodative amplitude at first, but it deteriorates as the time passes. Other causes that might disrupt accommodation are pupillary defects and recently associated with dry eyes (Motlagh and Geetha, 2022).

Karania and Evans (2006) examined the frequency of accommodative anomalies in patients that visited an optometry clinic, and identified it at 20%, although in reality it could be even more than that, since many eye-care practitioners do not incorporate accommodation testing into their practices. In general, 80% to 100% of accommodative abnormalities are cured (Daum, 1983).

The evaluation of a patient with accommodative dysfunctions may include the following areas, without excluding other examinations according to each case: patient history, ocular examination, visual

acuity, refraction, near point of convergence (NPC), near fusional vergence amplitudes, measurements of relative accommodation, accommodative amplitude and facility, stereopsis, ocular health assessment and systemic health screening (Cooper et al., 2010).

Vision therapy is often used by optometrists all around the world to treat accommodative dysfunctions. Other terms that are widely used for vision therapy are “vision training” and “orthoptics”. The purpose of vision therapy for accommodative dysfunctions is to increase the amplitude, speed, accuracy, and ease of the accommodative response. Several studies (Cooper, 1987; Berens, 1932; Sisson, 1938) suggest that accommodation can be modified with vision therapy. After the essential vision therapy sessions, the patient should be able to accommodate rapidly and without showing signs of tiredness. Marg (1951) also demonstrated that voluntary accommodation can be taught, as the accommodative system can be trained and Cornsweet et al. (1973) stated that biofeedback-based accommodation abilities can be applied to a variety of tasks. One study (Hoffman et al., 1973) showed that after roughly 26 therapy sessions, 87 percent of the patients with accommodative anomalies had eradicated their asthenopia and normalized their accommodative findings.

Cooper et al. (1987) found the preferred treatment for asthenopic symptoms brought on by accommodative abnormalities to be vision therapy. In his study, patients with asthenopia who received monocular accommodative amplitude (AA) therapy saw a remarkable improvement in their accommodative amplitudes, a decrease in their accommodative time constants, and a considerable improvement in their symptoms. The control group, on the other hand, didn't show any evidence of these alterations. When the control group got therapy equal to that given to the experimental group, symptoms were similarly reduced, and accommodative function was achieved. Moreover, Liu et al. (1979) assessed the effectiveness of orthoptics for accommodation problems and mentioned that in addition to removing symptoms, accommodating therapy exhibits objective changes in the accommodative response's velocity and a corresponding decline in time constants that are measured before and after treatment. Bobier and Sivak (1983) acknowledged this last allegation including the improvement of the latency of the accommodative response. Additionally, they claimed that therapy for AA can simultaneously increase positive fusional convergence (PFC), negative fusional vergence (NFV), and stereopsis.

For the patients that cannot follow a vision therapy program, plus lenses can be used. The purpose of plus lenses is to lessen the strain on the accommodation system and/or the degree of any existing esodeviation. The prescription of plus lenses appears to be significantly influenced by adaptation. Patients with accommodative dysfunction and asthenopia without significant heterophoria and those whose accommodative and fusional amplitudes are constrained but equal are less likely to benefit from the treatment. For the patients with an accommodating abnormality or an excessively high AC/A (accommodative convergence over accommodation) ratio, plus adds at near may be used.

Accommodative amplitude is normalized as part of the initial phase of therapy with the help of accommodative facility exercises. The second stage aims to expedite the response time to accommodative stimuli. To achieve generalization during this stage, it is advantageous to employ targets that gradually get smaller and to use a variety of stimuli. The patient is advised to perform the activity repeatedly until it becomes instinctive and effortless when the amplitudes return to normal levels. Binocular accommodative facility efforts can be carried out once monocular accommodative

facility has improved. With the binocular accommodative techniques, suppression controls may be needed. Typically, the binocular accommodative flippers' power is increased until the patient can have a clear image with ±2.50 D according to a specified criterion (Cooper, 1987). In the third stage, jumps or steps vergence stimuli are used. The patient is forced to perform large-jump accommodative and vergence movements rather than responding to gradually increasing stimuli. This last stage improves the patient's ability to alternate between vergence and accommodation. Last but not least, accommodation and vergence are combined using strategies that promote accommodation while maintaining stability in vergence, and vice versa. Accommodative and vergence reflexes are intended to be automated during this last stage of vision therapy.

Because both the accommodative and the vergence system are the most crucial for a person's long-term comfort, the effectiveness of vision therapy depends on the enhancement of both of them concurrently. The aim of the therapy program is restoring automatic, uncomplicated accommodative and vergence responses to every stimulus encountered. Amplitude improvement alone is considered insufficient.

## Accommodative Insufficiency

Accommodative insufficiency (AI), is a non-strabismic binocular condition in which the individual finds it difficult to stimulate accommodation. It is commonly accepted as the most frequently encountered type of accommodative dysfunction (Brautaset, 2008). The symptoms that a patient with accommodative insufficiency experiences, are sometimes similar to the ones that are associated with the onset of presbyopia. These may include blur vision in near distance, discomfort, eye strain, fatigue and difficulty concentrating while reading. Other symptoms for this condition are headaches, eye tension, sleepiness and delay in reading. In these cases the accommodative amplitude has a value lower than the expected for the patient's age. The flipper test with ±2.0 D usually fails and PRA is lower than -1.50 D.

Different studies have shown that the prevalence of accommodative dysfunctions among school-aged children is substantial. Borsting et al. (2003) and Abdul-Kabi et al. (2014) both researched the prevalence of accommodative insufficiency in school aged children. Brosting et al. (2003) found that the prevalence of accommodative insufficiency among 392 children that were tested was 10.5% and concluded that the dysfunction is considerably common and associated with increased symptoms. Abdul Kabi et al. (2014), examined 204 participants in Ghana searching for patients with accommodative insufficiency or accommodative infacility. The research revealed that 32% experienced accommodative insufficiency, 26% had accommodative infacility and 19% of the children had both dysfunctions.

Hussaindeen and Murali (2020) found that insufficiency of accommodation impacted 4.07% of Iranian students and in South Africa this percentage was 4.5%. According to their research, the criteria for a patient to be diagnosed with accommodative insufficiency are the following: 1) monocular accommodative amplitude (AA) needs to be at least 2 diopters below to the Hoftsetter's calculation (18.5 - 0.3 X Age) for the minimum acceptable amplitude according to age and below the expected norm. 2) Values more than +0.75 in monocular estimation method retinoscopy (MEM) 3) Accommodative facility testing fails with -2.0 with less than 6 cycles 4) Accommodative insufficiency co-existing with convergence insufficiency 5) Positive relative accommodation less than -1.25 diopters 6) Push-up monocular AA below expected according to age. In their literature review they also found that

accommodative insufficiency is frequently seen in children with special needs.

Vision therapy for accommodative insufficiency is based on the improvement of AA and accommodative facility (Liu et al., 1979). Target blur, disparity, and proximity are intentionally and carefully manipulated as part of vision therapy for accommodative insufficiency with the goal of normalizing the accommodative system (Rutstein et al., 1988).

The two most significant vision rehabilitation regimens for AI are orthoptic exercises like spherical flippers and plus lenses as reading additions (PLRA), however they are fundamentally different from one another. With PLRA, the accommodating system is given a "helping hand" in obtaining a clear retinal image in a relatively passive mode of therapy. However, the blur-driven sensors and the adaptive mechanism within the accommodative system will begin to function normally once it is possible to clear the retinal image. Spherical flippers, on the other hand, do not lessen the blur. The accommodative system learns to perceive and respond to a blurred image and as a result, the blur driven sensors and the adaptive mechanism will begin to function as they were supposed to (Ciuffreda, 2002).

Daum (1983), did a retrospective review of 96 patients diagnosed with accommodative insufficiency and examined the effects of vision training (orthoptic exercises) and/or a plus addition for near distance. The review revealed that 90% of the patients showed relief and more than half of them had both their subjective and objective problems solved. The average treatment period was observed at 3.7 weeks.

In another relevant paper, Brautaset et al (2008) compared the effect of orthoptics versus reading glasses in the treatment of AI. Twenty-four subjects participated in this study. Three different examiners saw all of the subjects and the third one assigned to each one of them either PLRA or flipper training. Ten patients were given PLRA and the other fourteen were given flipper treatment. After weeks of training, all subjects were re-examined and if they were still found with AI, they were referred again to the first examiner for additional treatment. Nineteen of the subjects were re-examined and all of those who did not need a second examination were from the group that was treated with flippers. Accommodative facility increased in both groups with a very close result (1.25 cpm in the PLRA group and 1.51 cpm in the flipper group) and the accommodative response did not change. After the treatment period all subjects presented results within the normal range, but, no statistically significant differences were found, due to the small improvement. Accommodative amplitude had a greater improvement in the flipper group. Similar results were presented by Sterner et al (2001) in their research about accommodative facility. The study also suggested that a period longer than 8 weeks is needed for AI treatment with orthoptics. The fact that dropout only happened in the flipper treatment group suggests that it might be harder to persuade participants to perform orthoptics compared to wearing glasses as it requires a higher amount of effort and determination.

## Accommodative Infacility

Infacility of accommodation is the inability to rapidly change the refractive power of the crystalline lens to focus on various distances. In this case, this ability is either failing or induces symptoms such as blur, headache and asthenopia (Hennessey et al., 1984). These patients always fail the ±2.00 D accommodative facility test monocularly and binocularly. AA is normal, but there may be abnormal relative accommodative findings, PRA or NRA. Some researchers consider accommodative infacility to be a precursor of myopia (Ruststein et al, 1988). Daum (1983) stated that if changing fixation

takes more than 1 second, there probably exists an abnormal condition like accommodative infacility. A year later, Daum (1984), published a paper investigating the results of orthoptic treatment in patients with accommodative dysfunctions and demonstrated that positive and negative fusional amplitudes, as well as stereopsis, can all benefit from therapy aimed to increase accommodative amplitudes. Vision therapy is highly effective for accommodative infacility and aims to increase the speed and flexibility of the accommodative system (Cooper et al, 1987).

Cooper et al., (1987) gave automated accommodative facility training to five patients who reported asthenopia as a result of accommodative deficits. All patients who underwent automated accommodative training displayed a significant rise in accommodative amplitude and a parallel decline in asthenopia. The most common changes that patients noticed were less blur and longer reading times. This study demonstrated how automated accommodative training can lower asthenopia and enhance accommodative ability.

Sterner (2001) published two papers examining in the first one the effect of flip lens training on the accommodative function, and in the second one the effect of accommodative facility training on relative accommodation. All of the subjects were diagnosed with an accommodative dysfunction and experienced problems at near work. In the first paper, the accommodative facility after the flip lens training was examined to determine whether there was an increase and also to investigate if it positively influences asthenopia and the rest of the visual symptoms the patients experienced. In the second paper, traditional dioptric treatment flipper was compared to a sham flipper treatment to see if other factors contributed to the subjects' accommodative performance. The experiments unequivocally show that accommodating facility training with a dioptric flip lens has a long-term impact, as it relieved the symptoms in all subjects and also improved both their NRA and PRA. It is unclear whether the symptom relief was associated with an increase in relative accommodation, an improvement to the accommodative facility, or both.

The results made it quite evident that short-term sham treatment had no discernible effect on symptoms and, if anything, had a negative impact on relative accommodation. Therefore, it is very likely that the therapeutic impact of the accommodating facility's dioptric treatment is related to the impact of the ±2.00 flip lenses.

## Accommodative Excess

Excess of accommodation (AE) is a state where the subject cannot relax their accommodation or exerts more accommodation than is necessary for the visual stimulus. It frequently goes hand in hand with convergence excess (Dictionary of Optometry and Visual Science, 2009). The patient complains of asthenopia, headaches, blurred vision after long periods of near work, sensitivity to light, eye tension, difficulty maintaining clear vision when changing focus between near and far distances and poor vision at the end of the day. Uncorrected hyperopia, very lengthy close work, emotional issues, spasms of accommodation, uveitis, and other factors could be at blame for its presence.

The tests that are considered important in the diagnosis and monitoring of AE, are cycloplegic retinoscopy, monocular and binocular accommodative facility, monocular estimate method (MEM), vergence tests and negative relative accommodation. The optometric signs that suggest the possible existence of accommodative excess include the following: reduced negative relative accommodation (NRA), low or negative value on monocular estimated method retinoscopy (MEM), few or no cycles with monocular +2.0 flipper (difficulty clearing vision), high positive relative

accommodation values (PRA), fluctuating visual acuity findings. (Baños et al., 2020).

Baños et al. (2020) conducted a very recent research in twenty four patients with accommodative excess as the primary disorder. Six of them already wore spectacle correction while the rest of them did not. The followed protocol was the same for all participants and it included 8 sessions of 45 minutes each, with the optometrist, and daily exercises for 20 minutes, for a duration of 4-5 weeks. In the first visit, 41.6% of the patients were out of the normal limits at the cover test for near fixation, while 95.8% of them were within normal limits at the cover test at distance. The only tool that was used, was a vision therapy protocol. After the end of the vision therapy program, 83.3% of the patients displayed cover test at near within normal limits. All patients showed improved results in NPC, stereopsis and visual acuity at the end of the vision therapy protocol. The study concludes that as long as the patient has the dedication to carry out the exercises at home and the exercises have attainable goals, vision therapy should be the primary choice in the treatment of AE.

## Accommodative Spasm

Spasm of accommodation can be unilateral or bilateral and is the involuntary contraction of the ciliary muscle that can be constant or intermittent (Rutstein et al., 1988). What happens is that the accommodative system unsuitably over-accommodates for a stimulus and the aetiology is probably psychogenic (Porter et al., 1995). This condition could cause pseudomyopia or latent hyperopia in which case the patient fails to relax accommodation even with the help of plus lenses (Goldstein and Schneekloth, 1996). Spasms of accommodation are caused by overstimulation of the parasympathetic nervous system, which may be linked to fatigue. It is a recurrent condition and it is rare to completely resolve and eliminate all symptoms. Most common symptoms of accommodative spasm are blurred vision, headaches, difficulty to shift focus from near to far, asthenopia, pain around the eyes and difficulty concentrating.

Vision therapy is used combining plus lenses. In most cases plus lenses alone are not sufficient to eliminate the spasm, so vision therapy must be prescribed. In cases where vision therapy is not helpful, a cycloplegic is prescribed.

Hyndman (2008) did a literature review and stated that the spasm of accommodation may develop due to various causes and the response to treatments is unpredictable and rely on the cause of onset. Therefore, there is no standardised treatment protocol and each case has to be considered separately. Strong cycloplegics, such as atropine, are frequently used for both diagnosis and treatment of the accommodative spasm. The use of milder cycloplegics in declining dosage, a reading addition, vision therapy exercises, and occasionally a combination of cycloplegics and vision therapy are often employed therapeutic modalities to re-establish accommodative stability (Rutstein et al., 1988; Hussaindeen et al., 2014). As the symptoms may differ in each person, the atropine dosage and the therapy protocol need to be evaluated according to each case. There is also a new treatment option that is presented by Satgunam and Holden (2018), which is called modified fogging technique and aims to relief accommodative spasm instantaneously. Modified fogging is based on Borish's delayed subjective test (Borish, 1945). In this new method, the patient is wearing a plus lens slightly higher than the expected average NRA value for 30 minutes, in order to force the accommodation to relax. Then, the patient is progressively defogged while being encouraged to read at a distance visual acuity chart. The defogging stops when the best visual acuity with the maximum plus is achieved. This leads to stability of accommodation and improvement of the visual acuity. However, further research needs to be done

to verify the effectiveness and to examine if it could be a legitimate replacement for vision therapy sessions.

## Vision Therapy for Accommodative Dysfunctions

Numerous studies conducted over the past 45 years have shown that it is possible to train the typical human accommodative system to increase response accuracy and timing. Such training entails rapid motor learning and considerably slower perceptual learning. Levine et al (1985) showed that accommodative facility training with ±2.0 D flippers for even a short daily session of a few minutes is capable to improve the overall responsiveness in asymptomatic young adults. Symptomatic patients can also be treated, according to studies. The first study that was conducted in symptomatic patients was in 1979 by Liu et al (1979) and the subjects were three optometry students. Although the sample was small, objective measurements of dynamic accommodation were made each passing week into the training program. For 4.5 to 7 weeks, subjects trained themselves at home for 20 minutes every day and the procedures that were used were only jump focus, plus-and-minus lens flippers, and pencil push-ups. Patients experienced significant decreases in time constants and latencies throughout treatment, which were closely associated with the disappearance of subjective symptoms. Additionally, flipper rates rose in all three individuals, and at the time of therapy's end, symptoms had either significantly improved or vanished altogether. These findings unequivocally prove that orthoptic therapy improved accommodation function in all three adult patients. Bobier and Sivak (1983) confirmed these results in adult patients where the improvements were tested again 4.5 months after the cessation of the treatment sessions and showed no regression.

Moreover, Weisz (1979) did a research in a group of children with accommodative disorders to go over the effectiveness of vision therapy in these patients. A control group was used that had perceptual-motor training instead of training for accommodation. Before and after the training programs, all individuals underwent a near point pencil-and-paper task to gauge changes in performance as a criterion of learning transfer and behavioural generalization. The research group showed a significant decrease in errors, unlike the control group that showed no important changes. The findings imply that accommodative training has transfer effects on near point performance in terms of increased accuracy for kids who have been diagnosed with accommodative dysfunctions.

In addition, Chen et al (2021) conducted a large study to determine the efficiency of vergence/accommodative therapy with the purpose to increase the accommodative amplitude and facility in children with convergence insufficiency and an accommodative dysfunction in a 16-week treatment period. Out of the 310 participants, 206 were randomly selected to receive vergence/accommodative therapy and the rest 104 participants formed the control group that received placebo therapy. Prior to the treatment, 56% of the participants in the therapy group showed decreased accommodative amplitude, and 63% of those in the placebo therapy group. With regard to decreased accommodative facility, these percentages were 34% and 36% respectively. At all four time points (weeks 4, 8, 12 and 16), the vergence/accommodative therapy group's mean amplitude of accommodation and accommodative facility, were statistically superior to the placebo therapy group. Most participants showed the greatest improvement in the first four weeks and then the improvement rate was relatively slower form week 4 to week 16. The final four weeks of the therapy did not significantly enhance the improvement of accommodative function and were rather focused on vergence procedures. It was also observed that the age of the participant did not

influence the results. This study demonstrated that vision therapy is effective in children with symptomatic convergence insufficiency and a coexisting accommodative dysfunction. Even in a program focused on the treatment of a vergence dysfunction, co-existing accommodative dysfunctions can still be positively impacted. Albeit, the effectiveness on the elimination of the symptoms was not assessed.

Vision therapy for accommodation has also been a proved to be an effective way to eliminate asthenopia. Accommodative facility training was given to five patients who reported asthenopia as a result of accommodative deficits. All patients who underwent accommodative training displayed a significant rise in accommodative amplitude and a parallel decline in asthenopia. The most frequently reported changes by patients were less blur and longer reading times. This study demonstrated how automated accommodative training can improve accommodative facility while also minimizing asthenopia (Cooper et al, 1987).

## Accommodative Dysfunctions Co Existing with other Binocular Disorders

Convergence insufficiency (CI) and accommodative insufficiency (AI) have been linked to symptoms that are identical and frequently occur simultaneously. There may be a dependent association between the intensity of CI's symptoms and its overall severity. However, when CI becomes more severe, the comorbidity of AI also becomes more prevalent. It has been demonstrated that AI alone can produce substantial symptoms. Marran et al. (2006) made the hypothesis that AI drives the symptoms in CI with comorbid AI, and that extra symptomology is caused by increasing coincidence of AI rather than higher severity of CI. Four groups of elementary school children were used in the research. 1) normal binocular vision 2) AI-only 3) CI-only and 4) CI with AI. They concluded that CI is an independent condition and can occur without the presence of AI. In children with only CI, when AI is not present, there were not significantly more severe symptoms than in children with normal binocular vision. The hypothesis is therefore confirmed.

## Accommodation. Relationship with Myopia

Investigative ophthalmology and visual science (IOVS) researchers analysed the accommodative facility in myopic and non-myopic eyes to see whether it could serve as a predictor, and they discovered that a myopic eye typically showed lower accommodative facility at distance (Pandian et al, 2006). Myopia and its evolution are both linked to decreased accommodating capacity and it results in prolonged accommodating response times. Myopia progression in young adults is independently correlated with increased latency of accommodation and decreased accommodative capability. Allen et al. (2009) studied a dual treatment of aberration control via contact lenses and vision therapy for improving accommodation. Ninety-three young people with myopia were included in the study and the tools that were used were custom designed contact lenses that control spherical aberrations and a vision training program to improve accommodation dynamics. The vision therapy protocol consisted of exercises with ±2.0 D flippers at 40cm for 18 minutes per day, for up to six weeks. Participants were instructed to keep up the visual training until they reached a minimum value of 25 cycles per minute. In comparison to the baseline values, in the vision therapy treatment group, both distance and near facility were considerably improved and were also significantly more than the control group. Even the minimal amount of vision training that took place as a result of data collection in the vision training control group was enough to raise accommodative facility rates. Therefore, the vision training was successful in changing the specific accommodative facility characteristics that

have been discovered to be abnormal in myopia (Pandian et al., 2006; O'Leary and Allen, 2001), and the study supports the efficacy of the treatment for accommodating facility.

### Equipment and Vision Therapy Exercises for Patients with Accommodative Dysfunctions

Accommodation training does not have to be expensive and it does not require a great amount of equipment. There can be change with the simplest of exercises and their variations for more advanced levels. Some of the most frequently used exercises for accommodative dysfunctions are:

• Monocular accommodative push-ups; that are performed with one eye patched and the use of a pencil. The therapist holds the pencil and moves it slowly towards the nose of the patient, while the latter is trying to keep it single and clear. Once the pencil is blur, the therapist moves it away and repeats. This exercise aims to increase and balance the accommodative amplitude between the two eyes. It is also frequently used for convergence insufficiency.

• Monocular Hart Chart; in which two identical letter charts are used, one for the patient to hold and one to be placed across the room. The patient is asked to monocularly read the letters from the far and the near chart alternately. This is an accommodation facility exercise as it relaxes and stimulates the accommodation at the same time.

• Monocular accommodative rock: with the use of a near chart and a flipper with plus and minus lenses. A plus lens is held in front of the patient's eye until they see the chart clearly. Then, the minus lens of the flipper is used. The power of the lenses is slowly increased aiming to augment the amount of accommodation that is stimulated or relaxed.

• Bi-ocular accommodative rock with loose prisms: using a vertical prism in one eye to induce double vision. Then a plus lens is put in front of one eye and a minus in front of the other. The patient is asked to read some letters from the top image and some from the bottom. Essentially, the patient is "forced" to isolate the accommodation of each eye to clear the image. In this way, accommodative facility is improved.

• Loose lens rock using a reading card, plus and minus uncut lenses and hopping cards. The patient's left eye is occluded, and they are asked to follow the instructions on the accommodative hopping cards, held at a distance of 40 cm, while alternating plus and minus lenses in front of their right eye, trying to clear the target. The goal is to restore the amplitude and facility of accommodation in normal levels.

These are only a fraction of the exercises than are used in a vision therapy practice. There is an abundance of different activities according to each diagnosis, that can help patients with accommodative dysfunctions improve their accommodative skills and, by extension, their daily lives and interactions with the space and the people surrounding them.

## DISCUSSION

The vast majority of the articles presented in this review support that vision therapy is an irreplaceable method of treatment for patients with accommodative dysfunctions. In fact, some cases may only benefit by vision therapy and see greater improvement in the severity of the symptoms experienced. Accommodative training also appears to have a positive impact in other vision aspects such as vergence dysfunctions. Although there is a plethora of existing research, further action needs to be taken in order to make accommodative training even more wide-spread, so that more people have the opportunity to have a better and effortless vision. All optometrists should be better informed

about the aspects and the benefits of vision therapy and educate and refer patients to a vision therapist when needed. Vision therapy also needs to be largely communicated so that more patients become aware of that option, as they are about glasses and contact lenses.

Vision therapy is to this day quite controversial among eye care professionals. According to the majority of the existing studies, vision therapy can effectively treat accommodative disorders. Only one paper was found to object on the effectiveness of vision therapy. Martinez's et al. (2009) evaluations of the literature in this area, which covered studies from 1986 to 2007, came to the conclusion that the reliability of previous studies was insufficient to prove that vision therapy is a successful treatment for non-strabismic binocular anomalies and accommodative dysfunctions. However, the study states that there is scientific proof that vision therapy is effective for treating convergence insufficiency.

According to Scheiman and Wick (1994), vision therapy is essential for the treatment of disorders such as accommodative excess, accommodative infacility, accommodative insufficiency and ill-sustained accommodation. Depending on the severity of the dysfunction, they have traditionally advised a vision therapy plan with 12 to 24 office sessions and home maintenance therapy (Scheiman and Wick, 2008). However, Ciuffreda (2002) evaluated some research on vision therapy for accommodative dysfunctions and discovered that the course of treatment should be shorter than twelve weeks.

Vision therapy has been proved to be a successful treatment for the function of the accommodative mechanism that reduces or eliminates the symptoms associated with accommodative dysfunctions. Additionally, it appears that the enhanced accommodative function is rather permanent following treatment (Rouse, 1987; Sterner et al., 1999). It has also been shown to be effective even in adult populations as well (Liu et al., 1979). Suchoff and Petito (1986), in agreement with Rouse (1987) and Sterner (1999) mention in their literature review that their findings support that visual therapy can alter visual functions and result in the alleviation of certain symptoms.

In order for vision therapy to be effective, the correct combination of exercises need to be carefully selected, as a wrong combination could result in the failure of the therapy protocol. Vision therapy aims to balance out visual processes in order to minimize symptoms when performing habitual visual tasks.

## CONCLUSION

Vision therapy is to this day quite controversial among eye care professionals, as it is frequently mentioned that further research needs to be done to prove its legitimacy. This literature review clearly states that there is a plethora of scientific evidence easily accessible that suggest that vision therapy is efficient and impactful. According to the majority of the existing studies, vision therapy can effectively treat accommodative disorders and their symptoms. In fact, it is found to be essential for the treatment of disorders such as accommodative excess, accommodative infacility, accommodative insufficiency and ill-sustained accommodation.

Vision therapy has been proved to be a successful treatment for the function of the accommodative mechanism that reduces or eliminates the symptoms associated with accommodative dysfunctions, most of the times, permanently. Every vision therapy program needs to be tailor-made according to each patient's needs and skills and has to be strictly followed in order to be effective. Based on the results of the research, it is necessary that

vision therapy becomes a more widespread method of treatment for accommodative dysfunctions.

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