ASSOCIATION OF ACCOMMODATIVE AMPLITUDE AND LAG WITH ATTENTION DEFICIT/HYPERACTIVITY DISORDER

by

Abigail Faith Veldkamp

Kristen O'Beirne Naszradi

This paper is submitted in partial fulfillment of the requirements for the degree of

Doctor of Optometry

Ferris State University
Michigan College of Optometry

May, 2012

ASSOCIATION OF ACCOMMODATIVE AMPLITUDE AND LAG WITH ATTENTION DEFICIT/HYPERACTIVITY DISORDER

by

Abigail Faith Veldkamp

Kristen O'Beirne Naszradi

Has been approved

May 2012

APPROVED:

_____, Faculty Advisor

Ferris State University

Doctor of Optometry Senior Paper

Library Approval and Release

ASSOCIATION OF ACCOMMODATIVE AMPLITUDE AND LAG WITH ATTENTION DEFICIT/HYPERACTIVITY DISORDER

I, Abigail Faith Veldkamp and I, Kristen O'Beirne Naszradi, hereby release this Paper as described above to Ferris State University with the understanding that it will be accessible to the general public. This release is required under the provisions of the Federal Privacy Act.

ABSTRACT

Background: Attention Deficit/Hyperactivity Disorder (ADHD) is one of the most common disorders diagnosed in children today.[1] Researchers have found links between tracking deficits, convergence insufficiency, and ADHD diagnosis, but little research exists on the relationship between accommodation and ADHD.[2,3] This study investigates whether there is a correlation between ADHD and accommodation dysfunction. *Methods:* Patients ages 7-18 in the Pediatrics Service at the University Eye Center—Ferris State University presenting for a comprehensive eye examination were invited to participate in the study. Patients and parents were given the opportunity to participate in an anonymous survey, produced and accredited by the American Pediatric Association, investigating symptoms of inattention, hyperactivity, and impulsivity or else stated that the patient had already been diagnosed without the need to complete the survey. The student clinician then recorded the patient's amplitude of accommodation and accommodative lag at the conclusion of the eye exam in order to correlate the diagnosis with accommodative findings. *Results:* Using t-test and chi-square analyses, a statistically-significant link between lower than average lag of accommodation and ADHD was shown. A link between amplitude of accommodation and attention disorders was not significant. *Conclusions:* While accommodative lag was shown to correlate with ADHD symptoms, further investigation is necessary in determining if accommodative amplitude correlates with attention and hyperactivity disorders.

ACKNOWLEDGMENT

The authors are very grateful for the guidance and academic support of Dr. Sarah Hinkley, which made this project possible. An additional thank you to Dr. Vandana Rajaram for her assistance in statistical analysis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Attention deficit/hyperactivity disorder (ADHD) is the most common pediatric neurobehavioral disorder diagnosed today.[1] The American Psychiatric Association estimates 1.6 to 2 million people suffer from ADHD.[4] During the past decade, the prevalence and treatment of ADHD has increased dramatically.[5] This disorder greatly impacts all aspects of life—social, academic, and family.[1] Up to forty percent of children with ADHD have learning disabilities.[6] Since ADHD is diagnosed by subjective symptoms and behavioral assessment,[2] the diagnosis and treatment of ADHD is controversial. There is current debate as to whether children with visual functioning deficits are misdiagnosed as ADHD when it is in fact binocular, accommodative, tracking, or visual processing dysfunction contributing to their symptoms.[2,3,7] If that is the case, vision therapy may cure, or at least alleviate, ADHD tendencies by strengthening the visual system and aiding in perceptual selection, an essential component for attentiveness.[5] It is important to differentiate visual dysfunction from ADHD because ADHD medications can impact appetite, sleep, and growth—all critical in developing children.[2] Moreover, it is important for clinicians to recognize that symptoms can be worsened by medications because side effects include blur and difficulties accommodating.[8] This uncertainty in diagnosis had led to an overwhelmingly large number of parents concerned that their children are being misdiagnosed with ADHD.[2]

Various studies have been completed on how visual functioning can impact attentiveness. Feifel et al. proved a significant link between saccadic dysfunction and attention disorders.[3] Children diagnosed with ADHD are three times more likely to be

diagnosed with convergence insufficiency.[2] Eye teaming disorders cause strain and require significant effort in both coordinating eye position and focusing on a particular visual task. To find relief from strain, near tasks are avoided. As the day progresses, so does a child's frustration and inattention.

Visual efficiency is the term used to describe an individual's ability to clearly and efficiently obtain information about the visual environment.[9] Three skills are required to do so in a comfortable matter. The first two skills, binocular vision and ocular motility, have a profound effect on ADHD diagnosis. The third skill is accommodation.[9] While researchers have started to link visual function to ADHD, there is a lack of research specifically on whether accommodative disabilities contribute to ADHD tendencies.

Accommodation is defined as the focusing adjustment needed to see objects clearly. Currently, six percent of children, ages six through eighteen, have been diagnosed with accommodative problems.[9] The American Optometric Association states that of those patients that have been diagnosed with binocular vision problems, 60 to 80 percent have accommodative dysfunction. [10] This study specifically addresses two components of accommodation—amplitude and lag. Accommodative amplitude is the total amount of accommodation accessible to an individual. When individuals have less accommodation than expected for their age, they will experience intermittent blurred vision with near tasks.[9] This condition is referred to as accommodative insufficiency. Along with eyestrain, it can cause headaches, fatigue/sleepiness, reading problems, avoidance of reading tasks, and decreased comprehension.[9] Accommodative lag is a measure of the accuracy of accommodation. It is measured by the difference between the accommodative response and stimulus. If a patient focuses behind the target, it is

referred to as accommodative lag. If a patient focuses in front of the target, he/she over-accommodates compared to the stimulus.[10] This study also attempts to correlate accommodative lag with ADHD tendencies.

METHODS

Two means were used to determine a possible correlation between accommodative dysfunction and ADHD. First, ADHD diagnosis was determined through patient/parent declaration or symptom survey results, and second, accommodative amplitude and lag were clinically measured. When measuring these values of accommodation, Scheiman and Wick's, Clinical Management of Binocular Vision text was utilized for methodology.

Each patient ages seven to eighteen who presented to the University Eye Center for a primary care exam was offered the opportunity to participate in an anonymous survey produced by the American Academy of Pediatrics.[11] The patient and his/her guardian were first prompted to check-off a box as to whether the patient had been diagnosed with ADHD by a medical professional, and, if not, they were instructed to complete the survey. The survey consisted of eighteen symptoms of inattention, hyperactivity, and impulsivity. According to the American Academy of Pediatrics, if the patient is symptomatic for at least six of the first nine symptoms listed in the survey, the patient is symptom-positive for inattention. If the patient is symptomatic for at least six of the last nine symptoms listed in our survey, the patient is symptom-positive for hyperactivity/impulsivity.[11] See Appendix A for the survey. Patients were then grouped into either the "yes" or "no" categories for ADHD diagnosis based on previous diagnosis by a healthcare professional or by the positive diagnosis based on survey results.

The first clinical test investigated in our study was amplitude of accommodation, subjectively measured by pushup method. An accommodative target was held at arms length and slowly brought in towards the patient's nose, while the patient was optimally corrected. When the stated target blurred or became diplopic, or if the patient's eye turned out, the endpoint was reached. A ruler was used to measure the dioptric distance between the corneal plane and endpoint. The results were compared to normative age-based data, as determined through Hofstetter's formula, which states that average expected amplitude of accommodation is calculated by (18.5- [(1/3)*(age)]. Hofstetter further found that the minimum amplitude of accommodation for a given age is calculated by (15-[(1/4)*(age)].[12] The data was analyzed in comparison to both of Hofstetter's formulas.

The second test conducted was a measurement of accommodative lag. This was measured by either Monocular Estimation Method (MEM) Retinoscopy or Nott Retinoscopy. The first option, MEM, begins with the patient wearing his/her best correction and the clinician located at Harmon distance away from the patient. Harmon distance is defined as the distance from the patient's elbow to his/her middle knuckle.[12] The clinician uses a retinoscope to observe the direction of the light reflex while the patient fixates and reads aloud words that are located on a card surrounding the retinoscope head. If the direction of the light reflex is opposite or against the motion of the light beam, the patient has a negative lag; this individual has an accommodative response that occurs in front of the stimulus. If neutralization occurs, the stimulus equals the response. If the motion of the light beam is in the same direction or with the motion of the reflex, plus lenses are quickly placed in front of the patient (to prevent change in

accommodative response) until neutralization occurs. The amount of plus lenses that neutralizes the light response is the accommodative lag measurement.

To measure accommodative lag using the second method, Nott retinoscopy, the patient's best correction is placed in the phoropter and the patient reads aloud words located 40cm away on the near rod. Again, a retinoscope is used to observe the light reflex. If against motion is observed, the patient has a negative accommodative lag. If neutral, there is no accommodative lag. If with motion is observed, the clinician moves away from the patient until neutral motion is observed, at which point the total distance away from 40 cm is converted into diopters of lag. Normative data for both accommodative lag tests are +0.25 to +0.50 diopters.[11] Scheiman and Wick report that studies have found close interexaminer agreement between MEM and Nott methods; the MEM method, however, has been found to have a wider range of measurements than Nott.[12]

RESULTS

89 pediatric patients (42 males and 47 females) were surveyed in this study. Of the participants, 56 patients (21 males and 35 females) had exams that recorded both the amplitude of accommodation and the lag of accommodation. 13 patients (9 males and 4 females) had exams in which only the amplitude of accommodation was measured and the lag of accommodation was not measured (see Figure 1). 20 patients (12 males and 8 females) had exams in which neither the amplitude of accommodation nor the lag of accommodation was measured.

Based on the results of the survey, the participants were divided into two groups. Group 1 was defined as participants with no ADHD diagnosis and lack of enough

symptoms to indicate an ADHD diagnosis from the survey. Group 2 was defined as participants with an ADHD diagnosis or enough positive symptoms from the survey to be diagnosed with ADHD. Group 2 was further divided into groups 2a and 2b, where Group 2a represented participants who had been previously diagnosed with ADHD by a healthcare provider. Group 2b represented participants who were symptom-positive on the survey (see Figure 2). For this study, 61 of the 90 participants (67.7%) were in Group 1 and 29 (32.3%) were in Group 2, with 12 (13.3%) in Group 2a, and 17 (18.8%) in Group 2b (see Figure 3). These groups will be referred to in the following results.

Amplitude of Accommodation

The manifest amplitude of accommodation measured during the exam was compared to the expected amplitude of accommodation, which was determined by 18.5-[(1/3)*(age)].[12] In Group 1 patients, the average deviation from expected amplitude of accommodation was found to be -1.10D with a standard deviation of 3.20D, while Group 2 patients revealed a mean deviation from expected amplitude of -1.06D, with a standard deviation of 3.33 D. When Group 2 was subdivided, Group 2a revealed a mean deviation from the expected amplitude of accommodation of -0.20D, with a standard deviation of 2.40D. Group 2b patients displayed an average deviation from the expected amplitude of accommodation to be -1.40D, with a standard deviation of 3.30D (see Table 1 and Figure 2).

A one-tailed T test was performed on the data to determine if Group 2 patients showed a statistically-significant difference in the mean of the amplitude of accommodation when compared to the mean of Group 1 patients. The p-value was calculated to be .466 with a confidence interval of 95%. With $p \leq .05$ considered to be

statistically-significant, the results indicated that the mean amplitude of accommodation in Group 2 is not statistically different when compared to mean value of Group 1.

A chi-square analysis was also performed on the data to determine if there is a statistically-significant connection between being in Group 2 and having a reduction in amplitude of accommodation, or if there is no association. With 1 degree of freedom, the chi-square value was .13, which gives a probability (p) between .80 and .70 that having a reduction in amplitude of accommodation is independent from being a patient in Group 2. Therefore, the hypothesis that there is no association and the events are random is accepted.

In addition to the formula for average expected amplitude of accommodation, Hofstetter described a formula for determining the minimum expected amplitude of accommodation based on age. Using this formula (15-[(1/4)*age]),[12] the data was analyzed to determine if Group 2 participants were associated with an amplitude of accommodation at or below the minimum expected value for age when compared to Group 1 participants (See Table 2). It was found that patients in all groups displayed a mean amplitude of accommodation above the minimum expected value. Patients in Group 2a were measured to have an amplitude of accommodation that averaged 2.40D above the minimal expected value, while patients in Group 2b displayed a mean amplitude of accommodation only .94D above the minimum expected value. No group displayed more than 50% of patient encounters measured to be below the minimal expected value for amplitude of accommodation.

Lag of Accommodation

Of the survey participants, 22 were examined using the MEM method for determining accommodative lag, and 16 were examined using the Nott method. +0.25D and +0.50D were used as the normative values for lag of accommodation, as described by Scheiman and Wick.[12] Figure 3 illustrates the frequency of patients in each group who displayed a lag of accommodation that differed from the expected values in one or both eyes.

For patients in Group 1, the average accommodative lag was +0.50D in each eye. The median and mode were also +0.50D for each eye. For patients in Group 2, the average accommodative lag was +0.38D in the right eye and +0.33D in the left eye. The median value was +0.50D in the right eye and +0.38D in the left eye. In both eyes, the mode was +0.75D. Patients in Group 2a had a mean accommodative lag of +0.44D in the right eye and +0.50 in the left eye. The median value was +0.63D in each eye, with a mode of +0.75 in the right eye and no mode in the left eye. For patients in Group 2b, the average lag of accommodation was +0.35D in the right eye and +0.27D in the left eye. The median values were +0.38D in the right eye and +0.25D in the left eye for this survey-positive based group. The mode was plano in the right eye and +0.75 in the left eye (See Table 2).

A two-tailed T test was used to determine if patients in Group 2 displayed a statistically-significant deviation (either higher or lower) in mean lag of accommodation when compared to the mean of patients in Group 1. A p-value of .08 was calculated with a 95% confidence interval. When considering $p \leq .05$ to be statistically-significant, it was found that Group 2 patients did not display a statistically-significant mean deviation in

lag of accommodation when compared to patients in Group 1, although the p-value was very close to being significant.

A one-tailed T test was also performed on the data, using the alternate hypothesis that patients in Group 2 displayed a statistically-significant reduction in mean lag of accommodation when compared to patients in Group 2. A p-value of .04 was obtained with a 95% confidence interval. This p-value is significant when considering $p \leq .05$ to be statistically-significant. Therefore, our data indicates that the means do not differ by chance, and a statistically-significant difference in mean lag of accommodation exists between Groups 1 and 2 when considering only a reduction in lag of accommodation.

A chi-square analysis was also performed to determine if patients in Group 2 were more likely to exhibit a deviation in lag of accommodation in one or both eyes when compared to patients in Group 1. Patients in each group were marked as 'yes' or 'no' to having an abnormal lag in one or both eyes. With 1 degree of freedom, the chi square value was 13.505, which gives a probability (p) of less than 0.1% that having a deviation in lag of accommodation is independent from being a patient in Group 2. Therefore, the hypothesis that there is no association and the events are random is rejected, and our study indicates a connection between being in Group 2 and having a deviation in lag of accommodation in one or both eyes.

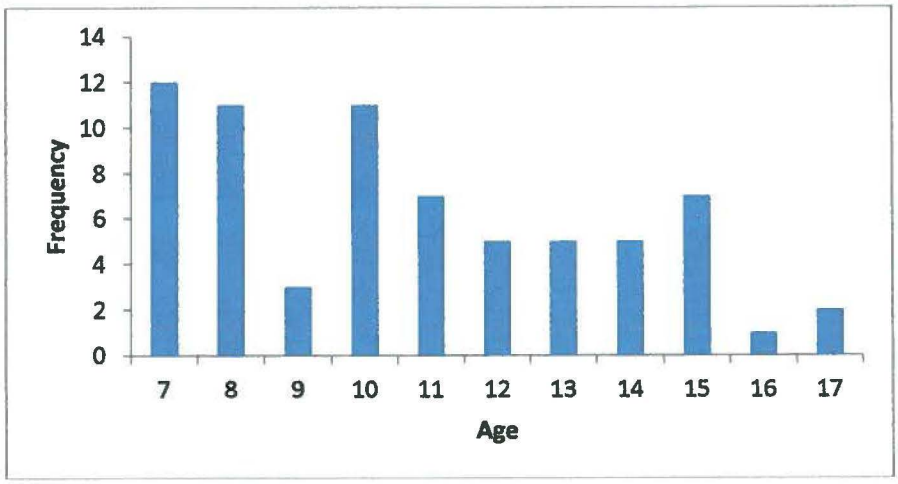

Figure 1. Age Distribution of Participants

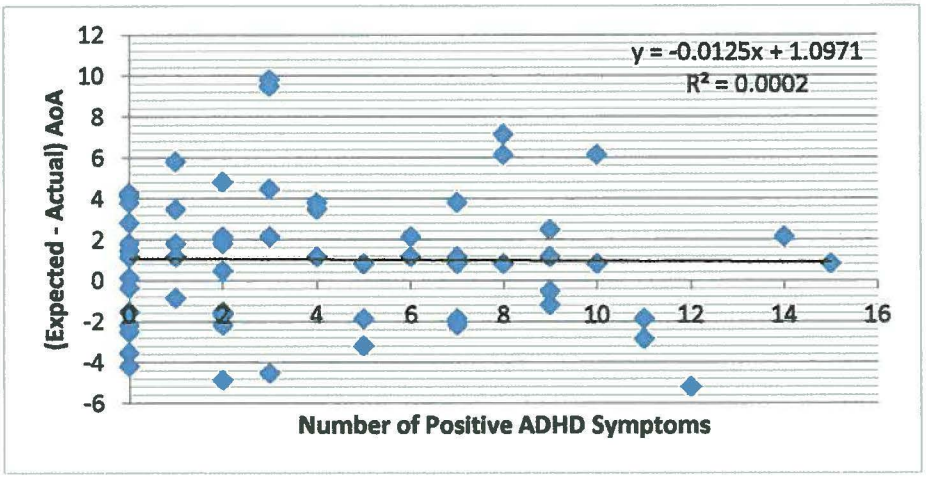

Figure 2. Comparison of Amplitude of Accommodation to Positive ADHD Symptoms

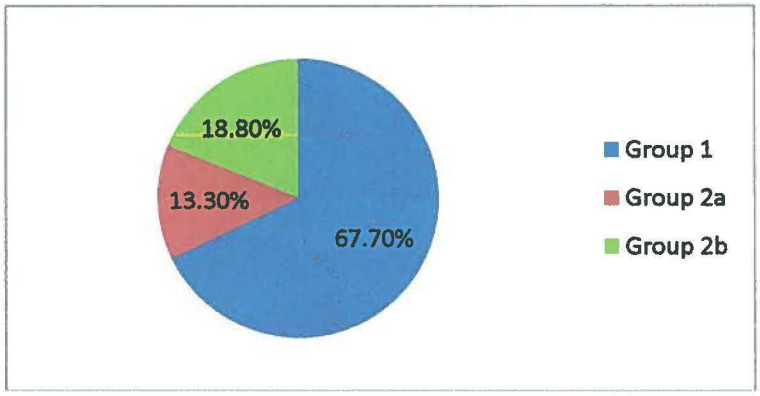

Figure 3. Distribution of Survey Participants Based on Survey Results

	Group 1	Group 2a	Group 2b
Mean deviation from expected amplitude of accommodation (D)	-1.1	-0.2	-1.4
Standard Deviation (D)	3.2	2.4	3.3

Table 1. Mean Deviation of Amplitude of Accommodation from Expected Value

	Group 1	Group 2a	Group 2b
Mean Above Minimum Expected Value (D)	1.5	2.4	1.4
Standard Deviation (D)	3.2	2.5	3.1
Number Below	11	2	6
Number at or above	34	6	15
Percent Below	32%	33%	29%

Table 2. Minimum Expected Amplitude of Accommodation

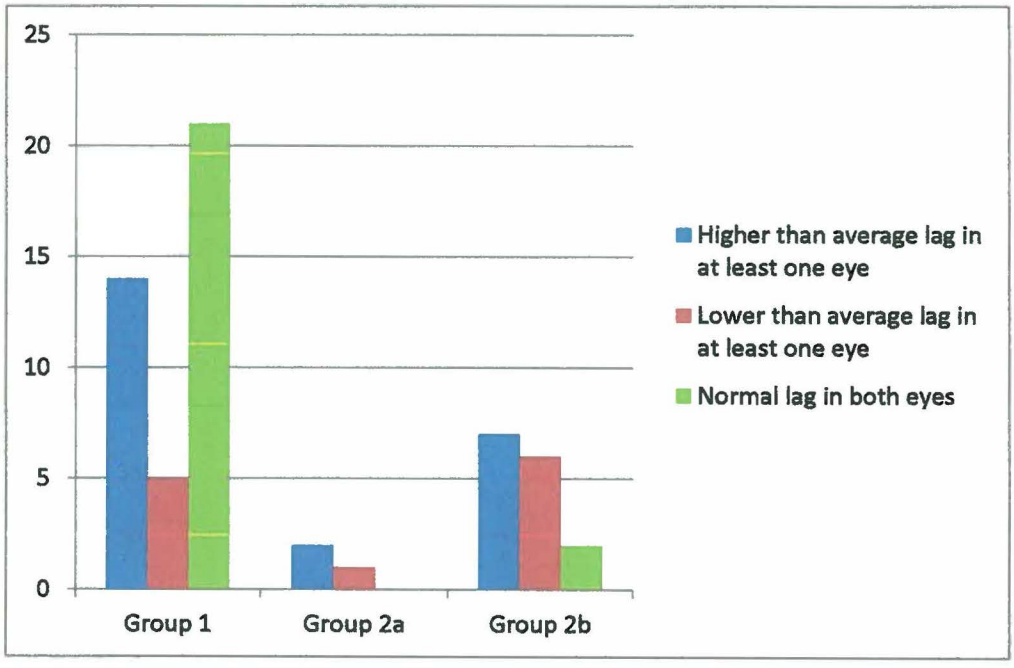

Figure 4. Lag of Accommodation

	Group 1 Lag OD/OS	Group 2 Lag OD/OS	Group 2a Lag OD/OS	Group 2b Lag OD/OS
Mean	.53/.51	.38/.33	.44/.50	.35/.27
Median	.50/.50	.50/.38	.63/.63	.38/.25
Mode	.50/.50	.75/.75	.75/NA	plano/.75

Table 3. Lag of Accommodation

DISCUSSION/CONCLUSIONS

While we were unable to define a statistically-significant link between amplitude of accommodation and attention disorders, our research indicates that there may be an association between lag of accommodation and attention disorders. The study finds that there is a statistically-significant link between having a deviation in accommodative lag in one or both eyes and having a diagnosis or symptoms of ADHD. Specifically, when the lag is quantified, these patients are more likely to have a lower than average lag of accommodation when compared to patients who had not been diagnosed with ADHD and did not report symptoms of ADHD. In both areas of accommodation, further research is needed to definitively conclude a correlation.

Other factors may also explain the statistically-significant correlation between abnormal lag of accommodation and ADHD diagnosis or symptoms. The established correlation between ADHD and convergence insufficiency may be responsible. For instance, a patient with convergence insufficiency may utilize accommodation to force convergence, thereby manifesting as a low lag of accommodation. In addition, it is plausible that the inattention of the child could contribute to erroneous examination findings, especially if the child is not concentrating on the stated target. Finally,

examiner error is also a possibility, and this study involved many different examiners leading to possible interexaminer differences.

It is important to educate all parents on the importance of routine eye exams for children; however, it is especially important to make sure children diagnosed with ADHD have a complete eye exam to ensure their visual system is functioning optimally. The American Optometric Association found over sixty percent of children with learning difficulties have undiagnosed vision problems.[13] Often children are unaware of their own vision problems because they are used to functioning that way. Parents must be educated on signs of vision problems in order to recognize when their child is having difficulties. Some of these problems include squinting, reversals, burning eyes, head turn, poor handwriting, use of a finger to keep place while reading, and holding objects very close.[5]

One of the reasons why it is so important to determine a better way of diagnosing and treating ADHD is the current rise in intentional abuse and misuse of prescription medications used to treat the condition. Stimulants are the most common treatment for ADHD, and they work by increasing alertness and readiness.[14] According to the IMS Health's National Disease and Therapeutic Index database, from 1998 to 2005 prescriptions for teenagers and pre-teenagers increased 133% for amphetamine products and abuse of these medications rose 140% in adolescents.[15] With the increased demand in the classroom and the high pressures on students today for successful academic performance, these medications offer a slippery slope for potential abuse in students with access to them.

Research and clinical experiences to date show a significant relationship between vision and attention deficits; however, more controlled studies are needed to further

evaluate the relationship between vision and ADHD. By more accurately diagnosing the cause of these disorders, better treatment regimens can be prescribed. If vision plays a significant role in ADHD, vision therapy may be a key component in helping those with the disease. By improving visual efficiency and visual attention, vision therapy offers hope for the improvement of symptoms related to ADHD secondary to visual etiologies.

Attention deficit disorders affect the lives of so many who have been diagnosed, misdiagnosed, or suffer symptoms that may indicate a diagnosis. Continued investigation into the underlying etiologies of ADHD is needed, including any possible relationship to problems of the visual system.

References

1. Centers for Disease Control and Prevention. Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among children. Morbidity and mortality weekly report 2010: 59(44): 1439-43.
2. http://www.childrensvision.com/ADD.htm. Children's Vision Information Network Website. Vision and ADD/ADHD-Eyestrain can make classroom attention impossible. 2005.
3. Castellanos FX, Marvasti FF, Ducharme JL, Walter JM, Israel ME, Krain A, Pavlovsky C, and Hommer DW. Executive function oculomotor tasks in girls with ADHD. Journal of the American Academy of Child and Adolescent Psychiatry 2000:39(5): 644-650.
4. http://www.add-adhd.org/attention_deficits_ADHD.html. ADD and ADHD Website. Attention Deficit Disorder and Attention Deficit Hyperactivity Disorder- A developmental approach. 2003.
5. Scheiman, MM and Rouse, MW. Optometric Management of Learning-Related Vision Problems- Second Edition. St. Louis, MO: Mosby Elsevier, 2006.
6. Cuffe SP. Prevalence and correlates of ADHD symptoms in the national health interview survey. Journal of attention disorders 2005: 9(2): 392 -401.
7. Damari DA, Liu J, and Smith KB. Visual disorders misdiagnosed as ADHD case studies and literature review. Journal of Behavioral Optometry 2000:11(4):87-91.
8. Granet DB, Gomi CF, Ventura R, and Miller-Scholte A. The Relationship between Convergence Insufficiency and ADHD. Strabismus 2005: 13(4):163-8.
9. Scheiman MM. Understanding and Managing Vision Deficits: A Guide for Occupational Therapists- Third Edition. Thorofare, NJ: SLACK Incorporated, 2011.
10. American Optometric Association. Optometric Clinical Practice Guideline: Care of the Patient with Accommodative and Vergence Dysfunction.
11. American Academy of Pediatrics. Clinical Practice Guideline: Diagnosis and Evaluation of the Child with Attention-Deficit/Hyperactivity Disorder. Pediatrics 2000: 105(5): 1162.
12. Scheiman, MM and Wick, B. Clinical Management of Binocular Vision Heterophoric, Accommodative, and Eye Movement Disorders- Third Edition. Philadelphia, PA: Lippincott Williams & Wilkins, 2008.
13. http://www.optometrists.org/therapists_teachers/NAACP_Resolution_Vision_Therapy_High_Risk.html. Optometrist Network Website. NAACP Passes Resolution on Vision, Learning, and High-Risk Populations at its 100th Anniversary National Convention. 2009.
14. http://www.add-adhd.org/ritalin.html. ADD and ADHD Website. DEA Report ADD/ADHD Statement of Drug Enforcement Administration. 1996.
15. Setlik MD, Bond GR, and Ho M. Adolescent prescription ADHD medication abuse is rising along with prescriptions for these medications. Pediatrics 2009: 124(3) 875-880.

APPENDIX A.

AMERICAN ACADEMY OF PEDIATRICS ADHD SYMPTOMS SURVEY

Symptom	NO	YES
Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities		
Often has difficulty sustaining attention in tasks or play activities		
Often does not seem to listen when spoken to directly		
Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)		
Often has difficulty organizing tasks and activities		
Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)		
Often loses things necessary for tasks or activities (eg, toys, school assignments, pencils, books, or tools)		
Is often easily distracted by extraneous stimuli		
Is often forgetful in daily activities		
Often fidgets with hands or feet or squirms in seat		
Often leaves seat in classroom or in other situations in which remaining seated is expected		
Often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)		
Often has difficulty playing or engaging in leisure activities quietly		
Is often "on the go" or often acts as if "driven by a motor"		
Often talks excessively		
Often blurts out answers before questions have been completed		
Often has difficulty awaiting turn		
Often interrupts or intrudes on others (eg, butts into conversations or games)		