Article ▸ # Association of Accommodative Amplitude and Lag with Attention Deficit/Hyperactivity Disorder

Sarah Hinkley, OD, Michigan College of Optometry at Ferris State University, Big Rapids, Michigan

Abigail Faith Veldkamp, OD, Grand Rapids, Michigan

Kristen O'Beirne Naszradi, OD, Westland, Michigan

ABSTRACT

Background: Attention Deficit/Hyperactivity Disorder (ADHD) is one of the most common disorders diagnosed in children. Researchers have found links between tracking deficits, convergence insufficiency, and a diagnosis of ADHD, but little research exists on the relationship between accommodation and ADHD. This study investigates whether there is a correlation between ADHD and accommodation dysfunction.

Methods: Patients aged 7-18 in the Pediatrics and Binocular Vision Service at the Ferris State University Eye Center presenting for a comprehensive eye examination were invited to participate in the study using an anonymous ADHD symptom survey produced and accredited by the American Pediatric Association or a stated previous diagnosis of ADHD. The student clinician or faculty member recorded the patient's amplitude of accommodation and accommodative lag at the conclusion of the eye examination in order to correlate the diagnosis.

Results: Using t-test and chi-square analyses, a statistically significant link between lower-than-average lag of accommodation and ADHD was demonstrated ($p=0.04$ and $p<0.1\%$, respectively). A link between amplitude of accommodation and attention disorders was not significant.

Conclusions: While lower-than-average accommodative lag was shown to correlate with ADHD (established or symptom-based diagnosis), further investigation is necessary to determine whether accommodative amplitude correlates with ADHD.

Keywords: accommodation, accommodative lag, attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD), focusing

Introduction

Attention deficit/hyperactivity disorder (ADHD) is the most common pediatric neurobehavioral disorder diagnosed in the United States.[1] The American Psychiatric Association estimates that 1.6 to 2 million people suffer from ADHD.[2] During the past decade, the prevalence and treatment of ADHD has increased dramatically.[3] This disorder greatly impacts all aspects of life: social, academic, and family.[1] Up to 40% of children with ADHD have learning disabilities.[4] Since ADHD is diagnosed primarily by subjective symptoms and behavioral assessment,[5] the diagnosis and treatment is controversial. There is current debate as to whether children with visual functioning deficits are misdiagnosed as having ADHD when a binocular, accommodative, tracking, or visual processing dysfunction is contributing to their symptoms.[3,5,6] If that is the case, vision therapy may alleviate or reduce ADHD tendencies by relieving strain on the visual system, in turn aiding in perceptual selection, an essential component for attentiveness.[3]

It is important to differentiate visual dysfunction from ADHD because ADHD medications can impact appetite, sleep, and growth, all critical to child development.[5] Moreover, it is important for clinicians to recognize that symptoms can be worsened by medications because side effects include blur and difficulty accommodating.[7] Uncertainty in diagnosis has led to a large number of parents concerned that their children are being misdiagnosed with ADHD.[5]

Various studies have examined how visual functioning can impact attentiveness. Feifel, et al. showed a significant link between saccadic dysfunction and attention disorders.[3] Children diagnosed with convergence insufficiency are more likely to report symptoms if they also suffer from parent-reported ADHD.[5] 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 obtain information about the visual environment clearly and efficiently.[8] Three skills are required to do so in a comfortable manner. The first two skills, binocular vision and ocular motility, have a profound effect on ADHD diagnosis, while the third skill, accommodation, has a poorly understood relationship.[8] 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 age six through eighteen have been diagnosed with accommodative problems.[8] The American Optometric Association states that of those patients who have been diagnosed with binocular vision problems, 60 to 80% have accommodative dysfunction.[9] 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 blur 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.[8] 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.[9] This study also attempts to correlate accommodative lag with ADHD tendencies.

Dr. Hinkley talks about the study examining the relationship between accommodation disorder and ADHD in patients.

Methods

Two methods were used to determine a possible correlation between accommodative dysfunction and ADHD. First, a diagnosis of ADHD was determined through patient/parent declaration or symptom survey results, and second, accommodative amplitude and lag were measured clinically using Scheiman and

Wick's *Clinical Management of Binocular Vision* text for methodology.[10]

The study received approval from the Ferris State University Institutional Research Board for research on human subjects. Each patient aged seven to eighteen who presented to the University Eye Center Pediatrics Service for a primary care examination was offered the opportunity to participate in an anonymous survey produced by the American Academy of Pediatrics with parental consent.[11] If consent was provided, the patient's parent and/or guardian was prompted to check a box as to whether the patient had been diagnosed with ADHD by a medical professional; if not, they were instructed to complete the symptom 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 the survey, the patient is symptom-positive for hyperactivity/impulsivity (Appendix A).[11] Patients were then grouped into either the yes or no categories for ADHD diagnosis based on previous diagnosis by a healthcare professional or by positive diagnosis based on survey results. If the subject was an established patient at the University Eye Center within approximately the last six years, previous records of eye examinations were available to the researchers. However, this information was not used for purposes of the study, and only data obtained on the day of the examination were included. The medical records of the subjects from their primary care physician or pediatrician were not available to the researchers.

The first clinical test investigated in our study was amplitude of accommodation, subjectively measured by push-up method. An accommodative target was held at arm's length and slowly brought in towards the patient's nose, while the patient was optimally corrected. When the patient stated that the target blurred (or doubled, if blur did not occur), or if the patient's eye turned out, the endpoint was recorded. A ruler was used to measure the dioptric distance between the corneal plane and the endpoint. The results were compared to normative age-based data, as determined by Hofstetter's formula: 18.5-[(1/3)(age)] for the average expected amplitude of accommodation. Hofstetter further found that the minimum amplitude of accommodation for a given age is calculated by the formula 15-[(1/4)(age)].[10] 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 MEM begins with the patient wearing his/her best correction. The clinician is located at the Harmon distance away from the patient. Harmon distance is defined as the distance from the patient's elbow to his/her middle knuckle.[10] 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, also called a lead of accommodation; this individual has an accommodative response that occurs in front of the stimulus. If neutralization of the reflex 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 and removed again while the eye is scoped (to prevent change in accommodative response) until neutralization occurs. The dioptric amount of plus that neutralizes the light response is the plus lag, also called the lag of accommodation.

To measure accommodative lag using Nott retinoscopy, the patient's best correction is

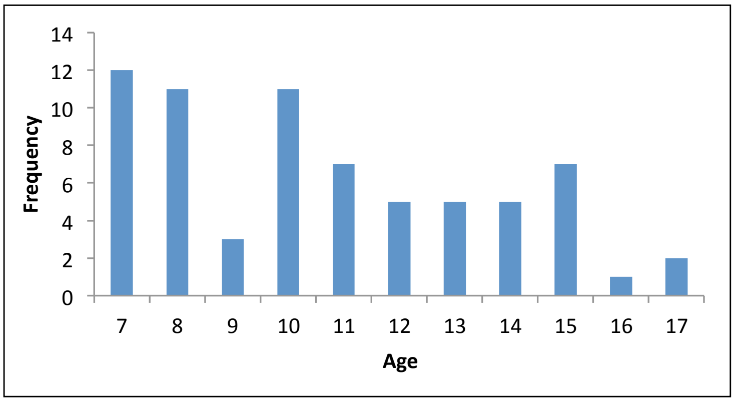

Figure 1. *Age distribution of participants with measured amplitude of accommodation or lag of accommodation.*

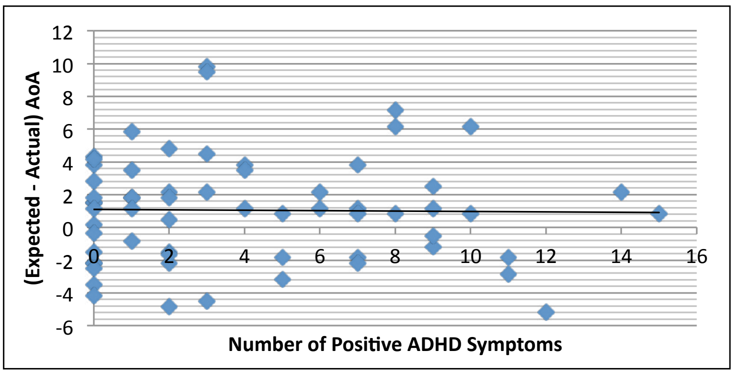

Figure 2. *Comparison of amplitude of accommodation (AoA) to positive ADHD symptoms on survey.*

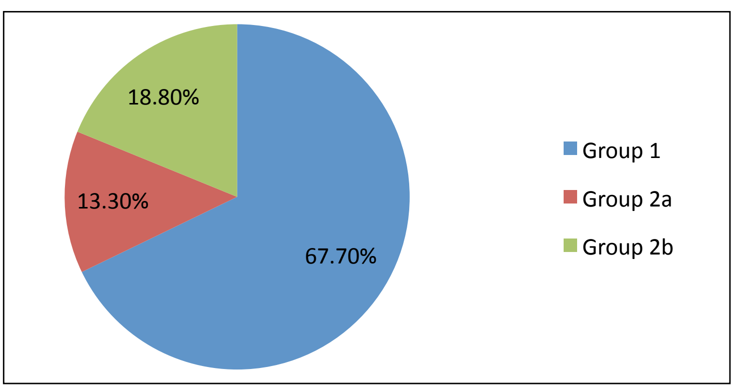

Figure 3. *Distribution of survey participants based on survey results.*

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 or lead of accommodation. 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 accommodative lag. Normative data for both accommodative lag tests are +0.25 to +0.50 diopters.[10] Scheiman and Wick report that studies have found close inter-examiner agreement between MEM and Nott methods; MEM, however, has been found to have a wider range of measurements than Nott.[10] Another recent study is contradictory, noting a significant difference between lag findings using the two measurements.[12] Because the study occurred in an operating eye clinic with examiners having a preference for one measurement versus the other, the study allowed the use of either measurement.

Results

Eighty-nine pediatric patients (42 males and 47 females) consented to participate in this study. Of the participants, 56 patients (21 males and 35 females) had examinations that recorded both the amplitude of accommodation and the lag of accommodation. Thirteen patients (9 males and 4 females) had examinations in which only the amplitude of accommodation was measured and the lag of accommodation was not measured (Figure 1). Nineteen patients (11 males and 8 females) had examinations in which neither the amplitude of accommodation nor the lag of accommodation was measured and were excluded from the amplitude of accommodation and lag of accommodation data analysis.

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 six positive symptoms needed to indicate an ADHD diagnosis from the survey. Group 2 was defined as participants with an ADHD diagnosis or at least six positive symptoms from the survey, considered for purposes of the study as 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 (Figure 2). For this study, 61 of the

Table 1: Selected Pre- and Post-Training Data

	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 2: Minimum Expected Amplitude of Accommodation

	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 3: 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

89 participants (68.5%) were in Group 1, and 28 (31.5%) were in Group 2, with 12 (13.3% of total participants) in Group 2a and 16 (18.0%) in Group 2b (Figure 3). These groups will be referred to in the following results.

Amplitude of Accommodation

The binocular manifest amplitude of accommodation measured during the examination was compared to the expected amplitude of accommodation.[13] The effects of convergence were not factored out in order to represent the manner in which the average clinician would obtain the measurement. Rather than looking at amplitude of accommodation as merely a measure of accommodative ability, this study assesses the clinical finding as a measurement in which both accommodation and convergence are in play. In Group 1 patients, the average deviation from expected amplitude of accommodation, with contributing convergence, 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 3.33D. 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 (Table 1 and Figure 2).

A one-tailed t-test showed the group mean difference in the amplitude of accommodation with contributing convergence not to be statistically significant ($p=0.466$). A chi-square analysis was performed to determine whether there was a statistically significant connection between being in Group 2 and having a reduction in amplitude of accommodation with contributing convergence. With 1 degree of freedom, the chi-square value was 0.13. This gives a probability between 0.80 and 0.70 that having a reduction in amplitude of accommodation was independent from being a patient in Group 2. Therefore, the hypothesis that there is no association and that 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. The data was analyzed to determine whether Group 2 participants had an amplitude of accommodation at or below the minimum expected value for age when compared to Group 1 participants (Table 2). Patients in all groups displayed a mean amplitude of accommodation with contributing convergence 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 0.94D 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, with each eye evaluated separately to factor out convergence. The normative values for lag of accommodation, +0.25D and +0.50D as described by Scheiman and Wick, were used.[10] Figure 4 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.

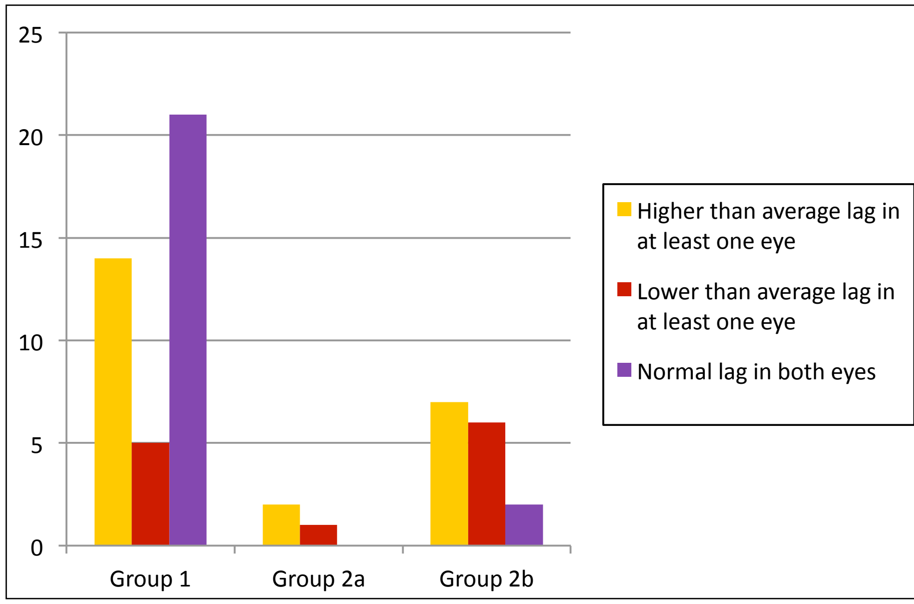

Figure 4. *Lag of accommodation.*

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 +0.75D 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. The mode was plano in the right eye and +0.75D in the left eye (Table 3).

A two-tailed t-test showed the group mean difference in the lag of accommodation average in both eyes not to be statistically significant (p=0.08), although the p-value was very close to being significant. A one-tailed t-test was also performed using the alternate hypothesis that patients in Group 2 displayed a statistically significant reduction in mean lag of accommodation of the average of both eyes when compared to patients in Group 1 (p=0.04). 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 whether 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. This gives a probability of less than 0.1% that having an abnormal lag of accommodation is independent from being a patient in Group 2. Therefore, the hypothesis that there is no association and that the events are random is rejected, and our study indicates a connection between being in Group 2 and having an abnormal lag of accommodation in one or both eyes.

Discussion

Interestingly, more patients in the study were labeled as positive for ADHD based on our symptom survey than had a previous diagnosis of the disease, supporting the idea that many undiagnosed cases exist. A shocking

32% of the study population presenting for comprehensive eye examinations was positive for ADHD based on previous diagnosis or symptoms.

While we were unable to define a statistically significant link between amplitude of accommodation and attention disorders, we acknowledge that by using binocular amplitude of accommodation measurements, convergence has an effect on the results. Therefore, we are measuring the accommodative and vergence systems as a clinical whole. This study should be repeated using monocular amplitude of accommodation findings for purer amplitude measurements.

Our research indicates that there may be an association between lag of accommodation and attention disorders, finding 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 were more likely to have a lower-than-average lag of accommodation when compared to patients who had not been diagnosed with ADHD and who did not report six or more symptoms of ADHD. In both areas of accommodation, further research is needed definitively to 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 use accommodation to force convergence, thereby manifesting a low lag of accommodation. The study attempted to factor out convergence by using monocular lag of accommodation findings. In addition, it is plausible that the patient's inattention could contribute to erroneous examination findings, especially if they were not concentrating on the stated target. This would most likely contribute to higher lags of accommodation versus lower. The study did not inquire about the use of prescription medications for ADHD that may have affected accommodative abilities. Finally, examiner error is also a possibility, and this study involved many different examiners, leading to possible inter-examiner differences in technique and recording. It is plausible to suggest that children with an ADHD diagnosis or positive symptoms may employ excess accommodation on a target in order to maintain attentive focus, attempting to compensate for a known attentive deficiency. Further research to examine a child's mindset of attentiveness as he/she engages in focusing on the near target during accommodative lag testing may be helpful.

It is important to educate all parents on the importance of routine eye examinations for children; however, it is especially important to make sure that children diagnosed with ADHD have a complete eye examination to ensure that their visual system is functioning optimally. The American Optometric Association found that 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 a certain way and assume it is normal. Parents and teachers must be educated on signs of vision problems in order to recognize when their child or student is having difficulties. Some signs that may indicate a problem with visual efficiency include squinting, reversals, burning eyes, head turn, poor handwriting, use of a finger to keep place while reading, and holding objects very close.[3]

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 for successful academic performance, these medications offer a slippery slope for potential abuse in students with access to them.

Research and clinical experiences demonstrate a significant relationship between vision and attention deficits; however, more controlled studies are needed to evaluate the relationship further.[6,7,16] By more accurately diagnosing the cause of these disorders and discovering any visual system connections, better treatment regimens can be prescribed. Cases not involving visual system deficiencies can be approached from a non-optometric or ophthalmologic viewpoint. 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 system etiologies.

Conclusion

Attention deficit disorders affect the lives of so many who have been diagnosed, misdiagnosed, or who 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 like accommodative dysfunctions.

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Correspondence regarding this article should be emailed to Sarah Hinkley, OD, at sarahhinkley@ferris.edu.

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