An Investigation of the Prevalence of Receded Near Point of Convergence in School-Aged Children with Attention-Deficit/Hyperactivity Disorder

A thesis submitted by

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Submitted to the Clinical Vision Research Program,

College of Optometry of Nova Southeastern University

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Directed and Approved by

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Keywords: Attention-Deficit/Hyperactivity Disorder, Near Point of Convergence, Accommodative Amplitude.

Abstract

PURPOSE:
The intention of this study was to determine if there was an association between receded near point of convergence (NPC) and diagnosis of attention-deficit/hyperactivity disorder (ADHD) in school-aged children as compared to neuro-normal children. Differences in accommodative amplitude were investigated as well.

METHODS:
This retrospective study was done by analyzing the data from examination records of fifty school-aged children between the ages of seven and seventeen. Twenty-five children in the experimental group with ADHD were age and gender matched to twenty-five neuro-normal children in the control group. The average of each patient's NPC break and accommodative amplitude values were used to conduct a t-test which examined if there was an association between them and a diagnosis of ADHD.

RESULTS

There was no significant difference between the average NPC break points of the neuro-normal group and the ADHD group ($t(24)=1.06479$, $p= .14615$). There was a significant difference between accommodative amplitude between the two groups $t(24)=3.454$, $p= .0012$ $p<0.05$). The ADHD group had significantly lower accommodative amplitude levels.

CONCLUSIONS:
It was expected that NPC values would be reduced in children with ADHD as compared to their neuro-normal counterparts, but there was no significant difference found. There was a significant difference in accommodative amplitudes between the control group and the ADHD group.

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ABBREVIATIONS:
NPC = Near Point of Convergence
ADHD = Attention-Deficit/Hyperactivity Disorder

Introduction:

Clear vision and good visual skills are important for school-aged children in many aspects of learning, especially in reading comprehension and mathematics [Franceschini et al., 2012]. Recently, it has been shown that children with neurodevelopmental conditions such as learning disabilities or attention deficit hyperactivity disorder (ADHD) have reduced visual skills as compared to neuro-normal children of similar backgrounds [Quaid & Simpson, 2013, CITTSG, 2008, Redondo et al., 2018, Puig et al., 2015, Varela et al., 2019, Mezer & Wygnanski-Jaffe, 2012, Granet et al., 2005, Mahone et al., 2009]. Understanding the prevalence of reduced visual skills in this patient population can help eye care professionals diagnose and create a treatment plan for children with ADHD who may be facing challenges in their scholastic environment.

There is no single test that can be used to definitively diagnose ADHD, but the tools that are used to evaluate children for this condition have progressed and become more refined [Posner et al., 2020]. If a parent suspects their child has ADHD, a child psychologist is able to complete thorough testing to confirm the diagnosis [Posner et al., 2020]. A pediatrician also has the ability to diagnose ADHD and prescribe medication as they see fit [Posner et al., 2020]. First, a medical history (including gestational details) and a family history should be taken [Posner et al., 2020]. The recommended ADHD diagnostic tool is the American Psychiatric Association's DSM-5 [Posner et al., 2020]. The DSM-5 lists multiple behavior criteria with examples in both "Inattention" and "Hyperactivity and Impulsivity" sections [Posner et al., 2020]. It is generally accepted that a minimum of six symptoms from either category is required to confirm ADHD in pediatric patients [Posner et al., 2020]. As the DSM-5 lists, children with ADHD can fall more into the "Inattention" subtype, or the "Hyperactivity and Impulsivity" subtype, or can possibly fall into a combination of the two categories [Posner et al., 2020].

Patients suspected of having ADHD show signs of poor attention, frequent over activity, and trouble with impulse control [Center for Disease Control, 2019]. The age of onset is typically around 7 years old, but this can vary between patients [Sayal et. al, 2018, Posner et al., 2020]. The symptoms of ADHD do not only affect children in the classroom; they can also cause issues at home and in social interactions with their peers [Center for Disease Control, 2019]. The prevalence ADHD in children under eighteen years of age is on the rise globally, with systematic reviews placing the average between two and seven percent [Sayal et al., 2018]. Sayal et al. (2018) showed that another five percent of children had attention issues and overactive tendencies, but did not meet all of the complete requirements for ADHD diagnosis.

ADHD is a chronic condition with many short term and long term treatment options [Posner et al., 2020]. The management of ADHD will vary on a case-by-case basis, with some treatment plans including medication if the presentation is more severe. For school-aged children, it is important to provide the appropriate academic support to help them learn more efficiently. This can include symptom intervention and behavior management when necessary [Posner et al., 2020]. ADHD is one of the thirteen conditions listed on the Individuals with Disabilities Education Act (IDEA) that entitles those children affected with an Individualized Education Plan (IEP) [Understood, 2020]. This is a special education plan that provides additional services to help children in need succeed in a classic learning environment. The members of an IEP team include the child's parent or guardian, a general education teacher, a special education teacher, a school psychologist and a district special education services representative [Understood, 2020]. These learning strategies and behavior management teach children with ADHD the skills that they need to help cope with their condition in the long term.

Children with ADHD have been shown to have a higher prevalence of binocular vision dysfunction as compared to neuro-normal patients [Quaid & Simpson, 2013, CITTSG, 2008, Redondo et al., 2018, Puig et al., 2015, Varela et al., 2019, Mezer & Wygnanski-Jaffe, 2012, Granet et al., 2005, Mahone et al., 2009]. Some of these conditions include accommodative problems, reduced vergence ranges, and saccadic deficiencies, each of which is discussed in the subsequent paragraphs.

First, Redondo et al. (2018) recently found that children with ADHD had weaker accommodative skills as compared to a control group. It was reported that there was a higher lag of accommodation and overall poorer accommodative accuracy in the ADHD group, which can have a significant impact on reading and on general school performance [Redondo et al., 2018].

Second, there have been mixed results in studies where researchers have investigated vergence ranges in children with ADHD [Puig et al., 2015, Varela et al., 2019]. Puig et al. (2015) did not find a statistically significant difference in vergence ability between a control group and an experimental ADHD group, although they did report that the ADHD group had a worse performance overall. Varela et al. (2019) found that a machine-learning model was able to determine if a child was a control or had ADHD with over ninety-six percent accuracy based on their vergence movements.

The Convergence Insufficiency Treatment Trial Study Group (2008) reported that children with ADHD had higher scores on the Convergence Insufficiency Symptom Survey, which indicates that in the group they studied, these patients were more symptomatic as compared to the children without ADHD. Granet et al. (2005) did a retrospective analysis and found that 15.9% of their pediatric patients with ADHD also had convergence insufficiency, which is twice the prevalence in the average population.

Third, there are many studies that report poor oculomotor skills in pediatric patients with ADHD as compared to neuro-normal controls. Mahone et al. (2009) found that children with ADHD with any type of ADHD had significantly worse visually guided saccades due to increased latency. Gargouri-Berrechid et al. (2012) had similar findings, although they only included seven subjects in both the control and ADHD groups.

Quaid and Simpson (2013) showed that in a Canadian sample size of fifty controls and fifty school-aged patients IEPs, hyperopia was the most common type of refractive error in the IEP group and these children had statistically significant slower reading speeds than their control counterparts. Although this study was not composed of a specific ADHD experimental group, ADHD is one of the disabilities listed under the IDEA act as a condition that children with IEPs may have.

There has been one previous study that measured the near point of convergence (NPC) in pediatric patients with reading problems as compared to controls [Palomo-Álvarez & Puell, 2010]. There was no significant difference found in NPC values between the two groups, although this study intentionally ruled out children with previously diagnosed learning disabilities from the experimental group [Palomo-Álvarez & Puell, 2010]. Thus, because NPC values in children with ADHD as compared to neuro-normal children has not been studied, the goal of our experiment was to determine whether or not NPC is a visual skill that is reduced in children with ADHD. Accommodative amplitudes were analyzed as well to determine if the small sample size studied followed the expected findings of an already known reduced visual skill in children with ADHD. Understanding the relationship between ADHD and visual skills in children helps clinicians, teachers, and other education support team members formulate a plan for the academic and social success of these patients.

Methods:

This retrospective study was done by analyzing the data from annual comprehensive eye examination records of fifty school-aged children between the ages of seven and seventeen. Twenty-five children in the experimental group with ADHD were age and gender matched to twenty-five neuro-normal children in the control group (mean age of control group, mean age of experimental group = 12.8 years old. 60% male, 40% female). Exclusion criteria included strabismus, amblyopia, best corrected vision worse than 20/20 in one or both eyes, children with development delays, children with genetic conditions, or children taking medication other than various predating ADHD medications. In this study, the medications that the children in the ADHD group were taking included Vyvanse (n=10), Focalin (n=2), Concerta (n=2), Quillichew (n=1), Intuniv (n=1), Adderrall (n=2), Strattera (n=1), and Dyanavel (n=1). Children with all refractive errors were included as long as their uncorrected or best-corrected vision was 20/20 in each eye and with both eyes together.

Each patient's objective NPC was measured in centimeters with a 20/40 single letter target during his or her comprehensive eye exam. The break measurement was taken when one or both of the eyes turned out and the recovery was noted when fusion was regained. The data collected included three measurements of the NPC break and of recovery. The average of each patient's point of break was used when tabulating the results. After chart review, a t-test was conducted to determine if there was any association between NPC values and diagnosis of ADHD. Differences in accommodative amplitude by pull away in diopters were also similarly investigated in with the single letter target.

This study was reviewed and approved by the Internal Review Board (IRB) of Nova Southeastern University.

Results:

The NPC values for both the ADHD and neuro-normal groups are shown in Tables 1 and 2. There was no significant difference between the average NPC break points of the neuro-normal group and the ADHD group (t(24)=1.06479, p= .14615). Both groups had three children with abnormal NPC results. Nineteen of the twenty-five children with ADHD reported taking one or more ADHD medications. The accommodative amplitude values for the ADHD and neuro-normal groups are shown in Tables 3 and 4. There was a significant difference of accommodative amplitude between the two groups (t(24)=3.454, p= .0012 p<0.05). The ADHD group had significantly lower accommodative amplitude levels. Accommodative amplitude still appears to reduce with age as physiologically expected.

Table 1: Control Group NPC Data Summary

Age	Gender	NPC 1	Recovery 1	NPC 2	Recovery 2	NPC 3	Recovery 3	Average NPC
7	M	5	8	8	10	8	10	7
9	F	TTN	TTN	TTN	TTN	TTN	TTN	0
9	M	TTN	TTN	TTN	TTN	TTN	TTN	0
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0
11	F	7	10	8	10	10	15	8.33
11	F	TTN	TTN	TTN	TTN	TTN	TTN	0
11	M	TTN	TTN	TTN	TTN	TTN	TTN	0
12	F	TTN	TTN	TTN	TTN	TTN	TTN	0
12	F	TTN	TTN	TTN	TTN	TTN	TTN	0
13	F	TTN	TTN	TTN	TTN	TTN	TTN	0
13	F	TTN	TTN	TTN	TTN	TTN	TTN	0
13	M	TTN	TTN	TTN	TTN	TTN	TTN	0
14	M	TTN	TTN	TTN	TTN	TTN	TTN	0
14	M	TTN	TTN	TTN	TTN	TTN	TTN	0
14	F	3	5	3	5	3	5	3
14	M	TTN	TTN	TTN	TTN	TTN	TTN	0
15	M	TTN	TTN	TTN	TTN	TTN	TTN	0
15	M	TTN	TTN	TTN	TTN	TTN	TTN	0
16	F	6	8	6	8	6	8	6
16	M	TTN	TTN	TTN	TTN	TTN	TTN	0
16	M	2	3	2	4	2	4	2
16	M	TTN	TTN	TTN	TTN	TTN	TTN	0
17	F	TTN	TTN	TTN	TTN	TTN	TTN	0

Table 2: Experimental Group NPC Data Summary

Age	Gender	NPC 1	Recovery 1	NPC 2	Recovery 2	NPC 3	Recovery 3	Average NPC	Medication(s)
7	M	5	8	8	10	8	10	7	NONE
9	F	3	5	3	6	3	5	3	NONE
9	M	TTN	TTN	TTN	TTN	TTN	TTN	0	NONE
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Focalin
10	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
11	F	5	8	5	8	5	8	5	Focalin
11	F	10	15	10	15	11	15	10.33	NONE
11	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Dyanavel
12	F	5	7	5	8	5	8	5	Quilichew
12	F	TTN	TTN	TTN	TTN	TTN	TTN	0	Strattera
13	F	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
13	F	2	4	2	4	2	4	2	Vyvanse
13	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
14	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
14	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
14	F	TTN	TTN	TTN	TTN	TTN	TTN	0	Intuniv
14	M	6	8	6	8	10	12	7.33	Vyvanse
15	M	7	10	7	10	10	15	8	NONE
15	M	TTN	TTN	TTN	TTN	TTN	TTN	0	NONE
16	F	TTN	TTN	TTN	TTN	TTN	TTN	0	Concerta
16	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse
17	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Adderall and Concerta
17	M	TTN	TTN	TTN	TTN	TTN	TTN	0	Adderall
17	F	TTN	TTN	TTN	TTN	TTN	TTN	0	Vyvanse

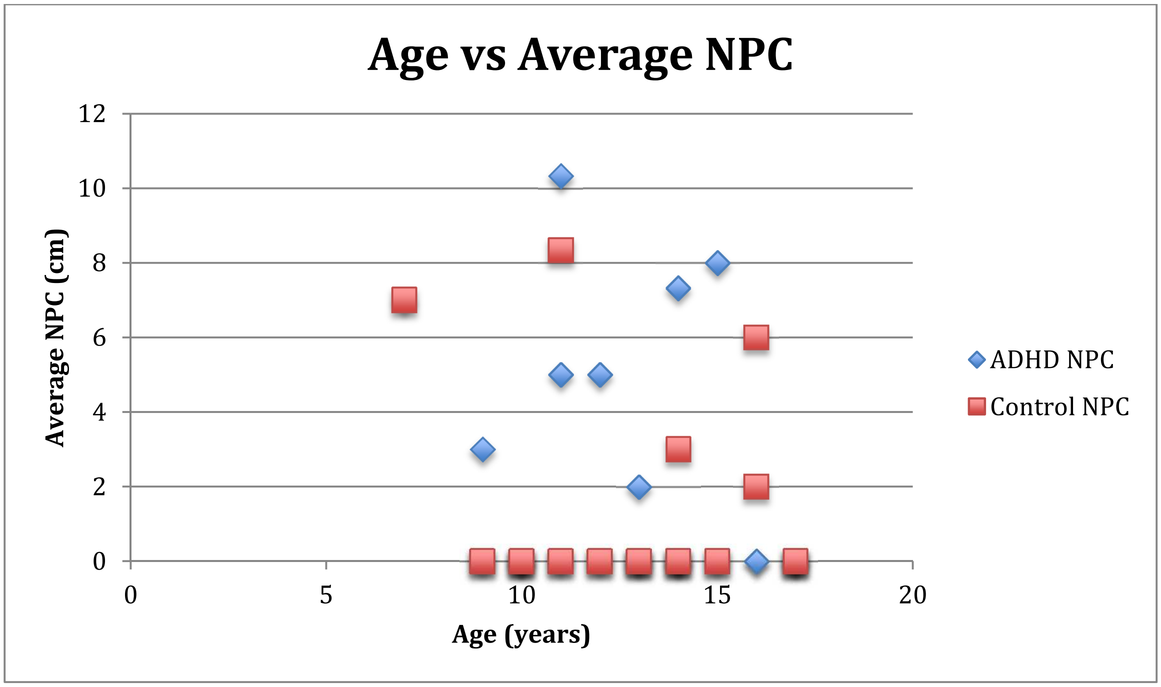


Figure 1: Graph of age vs average NPC values of each participant

Table 3: Control Group Accommodation Data Summary

Age	Gender	Amp of Acc (D)	Avg Acc for Age (D)	Difference (D)
7	M	12	16.2	-4.2
9	F	16	15.5	+1.5
9	M	15.5	15.5	0
10	M	15.5	15.2	+0.3
10	M	6	15.2	+1.2
10	M	15	15.2	-0.2
11	F	8	14.8	-6.8
11	F	14.5	14.8	-0.3
11	M	11	14.8	-3.8
12	F	15	14.5	+1.5
12	F	13	14.5	-1.5
13	F	13	14.2	-1.2
13	F	15	14.2	+1.2
13	M	11	14.2	-3.2
14	M	11	13.8	-2.8
14	M	13	13.8	-0.8
14	F	11	13.8	-2.8
14	M	14.5	13.8	+0.7
15	M	14	13.5	+1.5
15	M	14.5	13.5	+1.0

16	F	7	13.2	-6.2
16	M	10	13.2	-2.8
16	M	12	12.8	-1.2
16	M	12	12.8	-0.8
17	F	12	12.8	-0.8

Table 4: Experimental Group Accommodation Data Summary

Age	Gender	Amp of Acc (D)	Avg Acc for Age (D)	Difference (D)
7	M	6	16.2	-10.2
9	F	10	15.5	-5.5
9	M	13	15.5	-2.5
10	M	15	15.2	-0.2
10	M	12	15.2	-3.2
10	M	9	15.2	6.2
11	F	9.5	14.8	-5.3
11	F	8	14.8	-6.8
11	M	13	14.8	-1.8
12	F	9	14.5	-5.5
12	F	12	14.5	-2.5
13	F	10	14.2	-4.2
13	F	7	14.2	-7.2
13	M	9	14.2	-5.2
14	M	15	13.8	+1.2
14	M	5	13.8	-8.8
14	F	8	13.8	-5.8
14	M	11	13.8	-2.8
15	M	5	13.5	-8.5
15	M	14	13.5	+1.5
16	F	14	13.2	+0.8
16	M	9	13.2	-4.2
17	M	11	12.8	-1.8
17	M	12	12.8	-0.8
17	F	10	12.8	-2.8

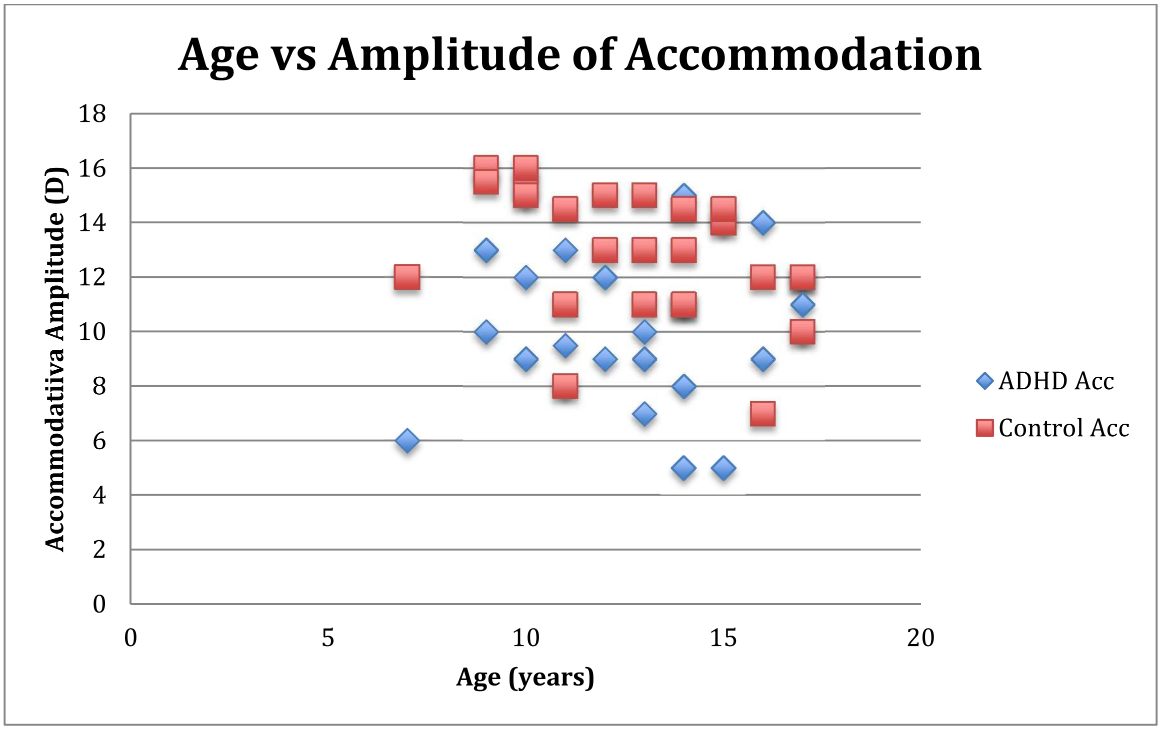
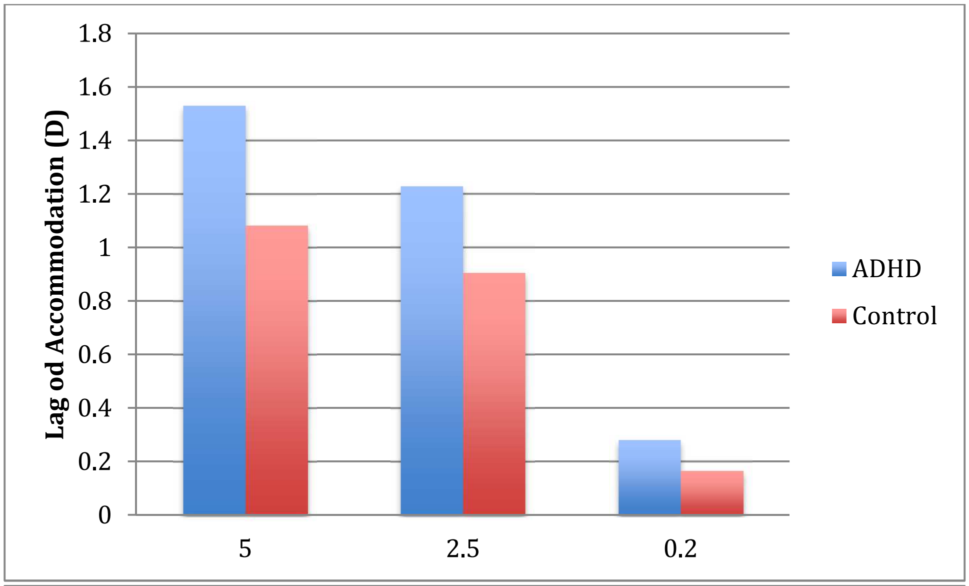


Figure 2: Graph of age vs accommodative amplitude values of each participant

Discussion:

Our investigation showed that there was no significant difference between the near point of convergence and a significant difference between the accommodative amplitude of an age matched group of neuro-normal and ADHD school-aged children. This suggests that the neurological mechanism underlying ADHD and makes children more susceptible to impaired binocular vision skills may not apply to the short-term convergence effort needed to execute an average NPC. This is in contrast to prior studies, which have suggested that the neural etiology of ADHD and poor visual skills are related. Tabulating the accommodative amplitude values shows that although the study cohort was small, the groups followed the expected pattern for this visual skill. As previously mentioned, Redondo et. al (2018) also found a statistically significant difference in accommodative skills in children with ADHD as compared to a neuro-normal control group. It was difficult to determine if the lower accommodative amplitude in the ADHD group in this study was innate or if it was a possible side effect of ADHD medication, which seventy-six percent of the patients in the experimental group were taking.



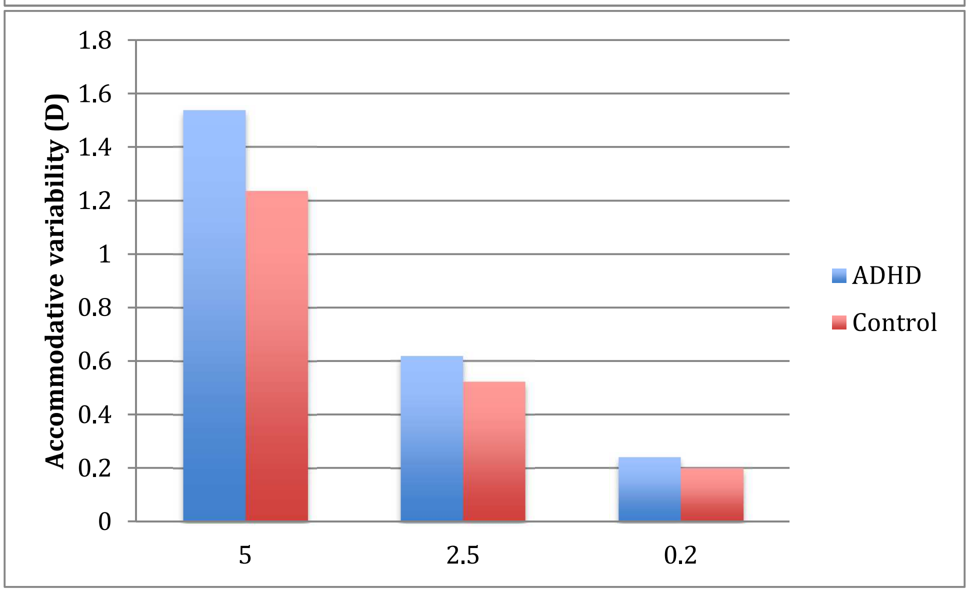


Figure 3: Replotted from Redondo et. Al (2018). The difference between lag of accommodation (D) and accommodative variability (D) for accommodative demands of 5.0D, 2.5D and 0.2D of control group as compared to ADHD group.

Many medical professionals will choose to begin ADHD treatment with support and intervention first, and then possibly add medication later as needed [Posner et al., 2020]. Others will choose to start with a course of medication as the initial treatment [Posner et al., 2020]. Management with medication is typically short term, as some patients develop a tolerance to the prescriptions over time [Posner et al., 2020].

Psychostimulant medications are most commonly used to treat ADHD. They are variations of methylphenidate or amphetamine [Posner et al., 2020]. These medications increase a patient's mental focusing ability to help improve attention and efficiency when working on academic activities [Posner et al., 2020]. The two most common short-term side effects are insomnia and appetite suppression, and long-term effects include possible stunted growth of height and/or weight [Posner et al., 2020]. If psychostimulant medications are not effective, doctors can prescribe non-stimulant medications such as atomoxetine or clonidine, but they are not as successful at controlling symptoms [Posner et al., 2020].

Psychostimulant medications such as Vyvanse or Adderall do have blurred vision listed as an adverse effect on the drug monograph, and it is recommended that a doctor or pharmacy be consulted if this side effect is experienced [Shire Canada, 2019, Shire Canada 2017]. Although blurred vision is reported in the psychostimulant monographs, there are very few studies reporting a specific mechanism or analyzing how children with ADHD are functioning if they experience this side effect. Soyer et al. (2019) postulated, "The effect on accommodation was triggered by the activation of the dopaminergic system". The subsequent accommodative insufficiency and the commonly noted dilated pupil in children taking psychostimulants for ADHD could be a result of the activation of this shared pathway.

In this study, only six of the twenty-five children in the experimental group were not taking any medication. Four of those six patients showed reduced amplitudes of accommodation as compared to the average expected values for their age. There were three children with ADHD who displayed receded NPC values. Two of those patients were not taking any medication, suggesting that psychostimulants likely do not cause reduced NPC values. However, both of these sample sizes are not large enough from which to draw any considerable conclusions.

It has been reported that the value for average NPC tends to increase with age, but values of five centimeters to seven centimeters are considered within the normal range for pediatric age groups [Abraham et. al, 2015, Yekta et al., 2016]. The average NPC value tends to increase with age, especially into adulthood [Abraham et. al, 2015]. NPC breaking and recovery points are part of the measurements used to assess patients for convergence insufficiency [Cooper & Duckman, 1978]. The neurological mechanism of ADHD is not yet understood [Posner et al., 2020]. It is possible that patients with ADHD have sufficient convergence ability for the short duration of NPC testing, but fatigue overtime or with more strenuous testing such as vergence ranges or accommodative testing. The convergence insufficiency symptom survey (CISS) is often used as part of the convergence insufficiency diagnosis, and many of the symptoms listed on the survey specify after a period of reading or near work [Nunes et al, 2020].

There are other neurological conditions apart from ADHD where NPC would be expected to be receded but has remained in the average range [van Donkelaar et al., 2018]. Van Donkelaar et al. (2018) studied males with and without a history of contact sport related concussion and did not find a significant difference between their NPC value measurements. Holden et al. found that NPC values were not receded as compared to average values in a group of twenty-four patients with Parkinson's or Parkinson like-conditions (although these conditions are not seen in school-aged children) [Holden et al. 2019]. Thus, the NPC pathway may remain unaffected when other parts of the brain circuitry are abnormal.

There were both strengths and flaws in the design of this study. As a retrospective study, there was no patient drop out and the data was collected quickly and efficiently. In terms of study flaws, it is difficult to generalize the results to a greater population with such a small study cohort. There may have been a significant result found between NPC values and the experimental group if there were more study participants. A longitudinal study design could have been valuable as well, because the researcher would have more control over the specific study design and would not be relying on past data. It should also be noted that the NPC and accommodative data were taken from exams that were done at different times of the day. It is possible that general end of day fatigue could have affected the results of patients that were seen in the afternoon, as compared to the morning.

Conclusion:

Many visual skills are impaired in school aged children with ADHD, including vergence ranges, saccades and pursuits, and accommodative skills. It was expected that NPC values would also be reduced in patients with ADHD as compared to neuro-normal counterparts, but there was no significant difference. There was a significant difference in accommodative amplitudes between the control group and the ADHD group. As mentioned, there were groups of patients with other neurological conditions that did not show a reduction in NPC as was expected. There were not enough participants to determine if taking ADHD medication impacted the results. Future research in this area should focus specifically on children with ADHD, and if differences in ADHD medication affects NPC and accommodative amplitude values in this patient population.

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