Accommodative Response in Children with Visual Impairment

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ABSTRACT

**Purpose:** The purpose of this pilot study was to objectively evaluate the accommodative response in children with visual impairment caused by macular pathology.

**Methods:** Ten children, ages 5-14, were enrolled into the study with previously diagnosed Stargardts, ocular albinism, macular hypoplasia, or rod/cone or cone/rod dystrophy. Visual acuity ranged from 20/80-20/250. Each subject's accommodative response was measured by the Grand Seiko WV500 autorefractor at demand distances of 33cm, 25cm and 20cm. The targets were vertical, high contrast, square-wave gratings that were one octave above threshold acuity. As the test distance decreased the grating size was decreased accordingly to ensure maintenance of a one octave above threshold target. This response was then converted to an amplitude response to determine the accommodative lead or lag. All testing was done through the subject’s best distance refraction.

**Results:** The subjects had five sub-types of accommodative response. The “negative slope lag” sub-type (one subject) showed increasing lags as the demand increased. The “fixed lag” sub-type (five subjects) showed a tendency to under accommodate a consistent amount regardless of the demand. The “fixed accurate” sub-type (one subject), demonstrated an accommodative response that was the most similar to a normal accommodative response. The “positive slope lag” sub-type (one subject), showed a large lag of accommodation initially and much more accurate accommodative response as the demand increased. And lastly, the “fixed lead” sub-type (two subjects), initially showed marked over-accommodation that decreased as the demand increased.

**Conclusions:** Although further investigation is needed the results of this study suggest that accommodation in pediatric patients with macular pathology can be variable and unpredictable and clinicians should not expect a normal accommodative response. Therefore, clinicians managing these types of patients should consider using near retinoscopy to assess each patient’s accommodative response prior to prescribing near addition lenses.

**Keywords:** accommodation, albinism, macula, pediatrics, Stargardt’s, visual impairment

Introduction

Providing appropriate near devices for children with visual impairment is critical for optimal educational outcomes. Many school-aged children with visual impairment can read typical size print by bringing the print to a close working distance, thereby utilizing relative distance magnification. As the target is brought closer, a high accommodative demand results, and pediatric low vision patients are often prescribed near addition lenses to meet the high accommodative demand. Very few textbooks discuss this issue; although they do address accommodation in visually impaired children, there is an assumption of near normal accommodative amplitudes and accuracy and no discussion of the means of measuring accommodative response is addressed. To date there have been only a few studies that have investigated accommodative responses in children with visual impairment.
impairments. Determining the ability and accuracy of accommodation in pediatric patients with visual impairment is a critical factor when prescribing optical devices.

The accommodative response to a specific near demand has been extensively studied in the visually normal population.4-9 At forty centimeters, Rouse et al10 measured the accommodative response of 100 children from kindergarten through 12th grade and found a mean lag of +0.33D (± 0.35) and +0.35D (± 0.34) for the right and left eyes respectively. Jackson et al11 reported that both eyes have a mean lag of +0.23D (± 0.29) when measurements were gathered from pediatric patients age 7.9 to 15.9 years. The research demonstrates that the accommodative lag found in children without visual impairment is approximately one third of a diopter. In contrast, studies of patients with systemic impairments such as Down syndrome12-13 and cerebral palsy14,15 as well as studies of patients with visual impairment such as amblyopia16-22 found lags that were significantly larger.

White and Wick23 evaluated six subjects with juvenile macular degeneration, ranging in age from 19 to 34 years of age who had acuities ranging from 20/120 to 20/240. The accommodative response was measured under three different conditions: Badal condition, monocular condition and binocular condition. Accommodative responses were measured using the SRI servo-controlled infrared optometer over demands ranging from 0-5 diopters. The subjects demonstrated poor accommodative accuracy at near viewing distances. White and Wick23 concluded that because of this poor accommodative ability and close working distance, “these patients would experience the effects of presbyopia at younger ages and require a reading lens of higher power than normally-sighted patients.”

Leat and Mohr24 evaluated 21 subjects with conditions including: albinism, rubella, Peter’s anomaly, retinitis pigmentosa, congenital nystagmus, homonymous hemianopia and refractive amblyopia. Subjects ranged in age from 5-34 years of age and had acuities ranging from 20/25 to 20/320. Accommodative response was measured with dynamic retinoscopy, using a modified Nott technique at 4, 6, 8, and 10 diopters. They found that the deficits of accommodation worsened with increasing accommodative demand in patients with ocular albinism. In contrast to the White and Wick23 study, they found more accurate responses at lower target demands, but increasing lags with increasing target demand. They also suggested that reduced visual acuity is not a sufficient explanation for the reduced accommodative accuracy.

The purpose of the present study was to explore the accommodative responses of pediatric subjects diagnosed with significant visual acuity loss (10/40-10/125) from various macular disorders (e.g. cone dystrophy, Stargardt’s disease, ocular albinism.) Unlike prior research this study used only young children and a completely objective method of measuring accommodative response. Use of an autorefractor allowed us to achieve objective measurements and standardization between investigators. The autorefractor was an open field design which allowed for more natural viewing conditions to be used.

Methods

Ten children, 5-15 years, with congenital macular disorders and moderate to severe visual impairment (20/80- 20/250) were enrolled in the study. Subjects were recruited from the patient base of the Southern California College of Optometry, Eye Care Center and the Blind Children’s Learning Center. The study followed the tenets of the Declaration of Helsinki, informed consent was obtained from the parent, and a child assent form was completed where appropriate after an explanation of the nature and possible consequences of the study. The study was reviewed

<table>
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<tr>
<th>Subjects</th>
<th>Age (years)</th>
<th>Visual Acuity/ Preferred eye*</th>
<th>Ocular Findings</th>
<th>Refractive Error</th>
<th>Diagnosis</th>
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Table 1: Patient characteristics

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and approved by the appropriate institutional review board (IRB). (See Table 1 for patient characteristics)

A review of the subject’s prior history and medical records was performed to determine diagnosis and visual acuity for study eligibility. At the study visit, non-cycloplegic retinoscopy was used to determine whether the subject’s habitual distance correction was within ± 1D sphere, -0.50D cylinder and within 5 degrees in axis. Any refractive findings outside of the above criteria were placed in a trial frame for use during the study measurements. No subjects required a change from their habitual correction. The subject’s monocular threshold distance visual acuity was measured using either the Bailey-Lovie chart or Lea symbols distance chart, depending on age and comprehension ability. Acuity was measured at 10 feet with high illumination directed at the chart. Near visual acuity was measured at 25 cm, a common habitual distance for children, using the Lighthouse single letter acuity card or Lea symbols near card.

Accommodative response was measured using the Grand Seiko WV500 Autorefractor at distances of 33 cm (3D), 25 cm (4D) and 20 cm (5D) (see Figure 1) using a vertically oriented, high contrast, square-wave grating pattern that was one octave above each patient’s threshold visual acuity (see Figure 2). The room illumination was full. At each test distance the grating size was maintained at one octave above threshold by decreasing the size of the grating. Measurements were taken through the subject’s distance correction. Five readings were taken from the patient’s preferred eye with the non-preferred eye occluded. The preferred eye was determined by subject report or by the eye with the best acuity if the patient did not identify a preferred eye. The median reading was then converted to a spherical equivalent and subtracted from the accommodative demand to determine the accommodative response.

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<th>Subject</th>
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Figure 1: Subject during testing with the Grand Seiko WV500. All subject’s lenses were clear, reflection from the autorefractor screen at close distance gives impression that the lenses were tinted.

Figure 2: Subject’s view of sine wave grating pattern used during measurements.

Figure 3: Provides a visual illustration of the sub-types as determined by data analysis. The mean accommodative error across the 3-5D range. p values and correlation coefficient (r) findings are listed by subject.
Due to the small number of subjects we had to use a more descriptive type of statistical analysis. On initial visual inspection, there appeared to be distinct differences in the patterns of accommodative response in children with visual impairment. Post-hoc single-case statistics were used to explore these observations.

To test for a stimulus–response slope significantly different from zero, a linear correlation was performed to obtain the correlation coefficient \( r \). To test for significant leads or lags of accommodation at the three stimulus levels, a \( t \)-test was performed with the null hypothesis of zero accommodative error. Because these tests were performed separately on each subject, the Bonferroni correction was used to correct for family-wise error rate. Figure 3 provides a visual illustration of the sub-types.

**Data Analysis**

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**Results**

Figure 4 displays the median accommodative responses at 33cm (3D), 25cm (4D) and 20cm (5D) of all ten subjects. The line in each boxplot represents the median value of each group and the shaded portion represents the inter-quartile range at each demand. Although there is a statistically significant difference among the medians (\( P=0.002 \)) the boxplot shows that the data are skewed and asymmetrical with extreme outliers and unequal upper and lower whiskers.

Figure 5 illustrates the accommodative response that was found in selected studies from the literature of children with normal accommodation for approximately the same age and across the same accommodative demands as the present study. Figures 6-10 illustrate the accommodative response versus the stimulus of the ten subjects.

Figure 6 shows the response of what we term the “negative slope lag” sub-type (one subject) who had a mean accommodative error (lag) of 4.39D over the 3-5D range.
increasing lags as the demand increased. As the target was moved closer and the accommodative demand increased, the subject’s accommodative response decreased (lag increased). The “fixed lag” sub-type (five subjects) who demonstrated a mean accommodative error (lag) of 2.08D over the 3-5D range.

The “fixed accurate” sub-type (one subject), with a mean accommodative error (lag) of 1.50D over the 3-5D range.

The “positive slope lag” sub-type (one subject), with a mean accommodative error of 1.34D over the 3-5D range, shows a large lag of accommodation initially and much more accurate accommodative response as the demand increased. Figure 10, the “fixed lead” sub-type (two subjects), shows over accommodation with a mean lead of 4.57D over the three to five diopter range. These subjects initially showed marked over accommodation that decreased as the demand increased. Both subjects were moderate to high myopes who habitually removed their glasses for near tasks. In general, the acuity, refractive errors, and ocular diagnosis did not appear to be predictive of the subject’s accommodative response.
The results of this study confirm previous findings that accommodative response in pediatric patients with visual impairment is considerably less accurate than normally sighted children. The accommodative response of children with visual impairment showed larger variability and was more complex than the expected accommodative response relative to that of children without visual impairment. Similar to the findings of White and Wick and Leat and Mohr, our data suggested that the majority of visually impaired subjects show a larger than normal lag of accommodation. As in the present study, White and Wick found that the subjects were divided into sub-types. One sub-type showed a minimal accommodative response with high lag of accommodation and the other group showed a lead of accommodation. When more visual cues, such as target proximity and binocular viewing were allowed, the accommodative response improved and more closely resembled that of a normally-sighted patient. White and Wick evaluated accommodative responses up to four diopters; however, the working distance for children with visual impairment is often much closer which requires higher levels of accommodation. Another issue is that White and Wick evaluated adult patients whose accommodative system may respond differently than that of a child.

Leat and Mohr evaluated several subjects that would not have been included in the present study as low vision, for example, those subjects with refractive amblyopia. When only considering the subjects with low vision, they found that there were two sub-types. Those that demonstrated a near normal accommodative response and those that demonstrated increased lag with increased demand. These results are very similar to those of our “fixed accurate” and “negative slope lag” sub-types.

Clinicians should not expect a normal accommodative response in children with visual impairment. Therefore, clinical methods relying on, or assuming, a normal response should be modified and accommodative response should be measured in this population by whatever method is clinically available prior to prescribing near reading corrections. By measuring the accommodative accuracy of these patients the clinician can base prescribing decisions on objective data rather than general assumptions. Accommodative response should be measured in this population by whatever method clinically available prior to prescribing near reading corrections.

Several limitations of this study should be noted. First the small sample size, this limitation did not allow for consideration or analysis of accommodative response related to specific disease condition or other demographic variables such as ethnicity. Additionally, some sub-types had very few members, future studies with a larger sample size may reveal additional types or determine that larger groups are more appropriate. Therefore, caution should be taken in inferring too much about the sub-types due to the small sample size. Additionally, the sample was collected from patients at two clinics and so the ability to generalize the findings might have been better through a multi-center design. Second, due to the cross-sectional design, these findings do not consider a view of accommodation over time. Future studies could re-examine the accommodative response on follow-up visits to determine repeatability. Lastly, the physical limitations of the open field autorefractor only allowed measurements up to 5D and many children with visual impairment habitually adopt a working distance of 10 centimeters or closer. Despite these limitations, the present findings offer important implications for clinical low vision management of children with macular diseases. Clinicians should...
use clinically available methods, such as MEM or other near retinoscopy techniques, to evaluate accommodative response in this population prior to prescribing near corrections.

Further research in this area is necessary to provide clinicians with a better understanding of the accommodative response in children with congenital macular disorders. Suggestions for future studies include measurement of accommodative response both monocularly and binocularly, and comparison to standardize clinical measured of accommodative accuracy. Binocular viewing may improve accommodative response as demonstrated in the White and Wick study. Use of targets with more accommodative detail may also improve the accommodative response. A more natural target may aid in achieving better attention and therefore better accommodative response.

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References