THE EFFECT OF DIFFERENT WORKING DISTANCES ON THE ACCOMMODATIVE RESPONSE

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ABSTRACT

Background: The accommodative response is an important tool that is helpful in the diagnosis of a variety of binocular vision disorders. By a patient's accommodative response, it can be determined if the patient is over-accommodating or under-accommodating. Monocular Estimation Method (MEM) and Nott retinoscopy are two common techniques that are used in a clinical setting to quantify the accommodative response. These techniques are clinically done at a setting of 40 centimeters, however most patients will hold their reading materials or near work at a distance closer or farther away than 40 centimeters. This project built upon previous work and further explored how varying working distances affect accommodative lag.

Methods: This study used Nott retinoscopy method, and MEM for estimating the accommodative response. Nott retinoscopy requires a near point rod, a retinoscope and a Snellen near target; while MEM requires a retinoscope with a near card attachment, and a set of -1.00 to +1.00 diopter (D) loose lenses in 0.25D steps. The subjects in this study ranged from 20-30 year old healthy optometry students who have vision that is 20/40 or better and a normal binocular vision system. Visual acuity was taken on eye of each participant as well as a gross examination for any heterotropias. Participants in the study were asked to wear their best spectacle correction when tested. Nott retinoscopy and MEM retinoscopy were each performed on each participant's right eye at three different test distances: 25 cm, 40 cm, and 50 cm. Each test was performed monocularly, meaning only the participant's right eye response was taken into consideration. The accommodative response for each test distance for each method was compiled into a Microsoft Excel document and analyzed. After testing was complete, the accommodative response at each testing distance was compared using statistical data analysis.

Conclusions:

Both the Nott and MEM showed similar normative values for the 40 cm working distance, with Nott being found to be +0.517 +/- 0.114 and MEM being found to be +0.517 +/- 0.334. As the working distance became less, results for both MEM and Nott both become more variable. The average Nott findings for 33 cm and 25 cm were +0.566 +/- 0.200 and +0.966 +/- 0.256 respectively, with the degree of variance increasing with decreasing working distance. These findings for Nott were highly statistically significant. In comparison,the MEM measured lag showed a direct relationship between working distance and accommodative lag. The average MEM measured lag findings for 33 cm and 25 cm were +0.383 +/- 0.208 and +0.266 +/- 0.240 respectively, with the degree of variance also increasing with decreasing working distance. These findings for MEM lacked the statistical significance found in Nott measurements.

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CHAPTER 1
INTRODUCTION

Depending on the source used, it is estimated that binocular vision and accommodative conditions are up to nine times more common than ocular disease in the pediatric population (age 6 months to 18 years old)[2]. Similarly, it is reported that the most common binocular vision disorder, convergence insufficiency, is prevalent in one to 25 percent of clinical patient encounters.[1]

Due to the high prevalence of binocular and accommodative conditions, it is important to understand the different components of the binocular system. This particular study assesses the accuracy of the accommodative system in regards to variability in test distance. In the exam lane, a standard 40 centimeter test distance is often used to assess the efficiency of a patient's binocular system. This distance, however, is not always the distance at which a patient's visual system is under stress throughout their day. Time has long since passed in which an individual uses their near vision for reading or writing at a 40 centimeter distance alone. Electronic devices such as the desktop computer have pushed that working distance back, while hand-held devices such as cell phones or tablets have moved that distance closer. Along with this comes the variability among patients in regards to arm length or overall comfort. With regards to these changes, it is important for the clinician to understand that binocular changes may vary in regards to variability in test distance. For these reasons, the investigators wished to understand how the variability in ones working distance can affect the clinician's findings and therefore ultimately affect the course of management.

A normal accommodative lag is typically between +0.25 to +0.75 D. However, a measurement of more than +1.00 D may indicate that a patient has accommodative insufficiency or accommodative infacility.[1] A measurement of -0.25 D or more can indicate that a patient suffers from accommodative excess.[1] However, these are normative values for a working distance of 40 centimeters. This study explores how the accommodative response can vary depending on how close or far away something is being held.

This study is building off of a previous study that was performed in 2016.[5] The previous study compared the differences in accommodative lag at different working distances, similar to the methods that are outlined later in this paper. This current study attempts to normalizes inconsistencies in the previous work in order to provide more reliable data, such as having all of the participants wear their spectacle correction and using the results of only the right eye. The particular study that was used as the foundation showed that results were statistically significant for the MEM, but not for Nott retinoscopy.[5] For this most recent study, the MEM target was also used for Nott so that there would be a similar cognitive demand between the two approaches. The accuracy for Nott was also increased by attaching a pointer stick to the retinoscope head so that the neutralizing distance could be more precisely measured. Using 0.25 D steps for all different measurements of the accommodative response was used to improve consistency. The goal of this study was to obtain more conclusive results than its predecessor.

There are other studies in which accommodative lag measurements have been taken at working distances other than 40 centimeters, however, most of these studies have been performed on children. One study in particular used distances of 25 centimeters, 16.7 centimeters, and 10 centimeters.[3] A working distance was justified of 25 centimeters as that is the distance that school-age children typically hold their near work at. The other distances were chosen to determine what the accommodative response was as it was stressed on distances that grew closer and closer to the participant. This study used the Nott dynamic retinoscopy method to determine the accommodative response. The results of this study showed that the mean lag of accommodation for children aged 4 to 15 years old was +0.30 +/- 0.39 D at 25 centimeters, +0.74 +/- 0.58 D at 16.7 centimeters, and 2.50 +/- 1.27 D at 10 centimeters.[4]

Our study does vary slightly from those before it, particularly in using a more strict guidelines for type of visual correction worn by participants. The 2016, as well as its predecessor, did not specify the type of correction used by its participants. Because of this, measurements were taken on some individuals wear contact lenses while others were wearing contact lenses. This study limited the participants to corrective spectacles only. Our study also varied in that it only included adult participants, and that it was also conducted at different working distances. Similarly, this studies like those before it also compared the results of both Nott dynamic retinoscopy and the MEM.

The researchers believe that the accommodative lag will vary as the working distance is varied. Specifically as the working distance is shortened, or as the accommodative demand is increased, the accommodative lag will also increase. For example, if at 40 centimeters the normative value is approximately +0.50 D, then we predict that the accommodative lag will increase when the distance is changed to 33 centimeters. This hypothesis was made using the results of the studies that have been previously performed.

It is our hope that our study will expand our knowledge of how the accommodative response changes in adult aged participants as the working distance is varied. This can give us a better understanding of how a patient's accommodative system is working now that we have new near tasks that are leading people to hold their near tasks closer as well as farther away.

CHAPTER 2
METHODS

This study was approved by the Ferris State University Institutional Review Board (IRB). A total of 15 participants with grossly normal acuity and binocular vision systems were used to gain data in this study. To qualify for the study, participants were required to wear their most up-to-date spectacle correction, have acuity no worse than 20/25 and have no gross binocular anomalies detected with a cover test. Their acuities were taken with their spectacle correction worn at a distance of 6 meters using the Canela computerized acuity system and then taken again at 40 centimeters using a Snellen near point card. After visual acuity was recorded, a cover test was performed, both at distance and near. Participants that had visual acuities worse than 20/40 and/or a significant misalignment of their binocular system were not allowed to proceed with the study.

After it was determined if the participant was a suitable subject for the study, their accommodative responses were taken using both MEM and Nott retinoscopy at three different working distances: 40 centimeters, 33 centimeters, and 25 centimeters. Only the participant's right eye was utilized in taking measurements with each method, and the patient waited 5 minutes between each station. Measurements were always taken from the furthest distance (40 cm) first, and ending with the closest distance (25 cm).

The first station collected dynamic accommodative information using the MEM. This procedure was performed with the participant wearing their spectacle correction and required the use of a retinoscope, age appropriate near target, and loose lenses laid out in 0.25 diopter steps. Accommodative data was taken at the three working distances listed previously. During the procedure the participant read the words on the accommodative target aloud while the researcher used the retinoscope to assess the horizontal meridian in the right eye. The researcher then used the loose lenses by placing them quickly in front of the participants' right eye to determine the point of neutrality. The result was recorded for each of the different working distances.

Station two collected accommodative information using the Nott retinoscopy method. This procedure was also performed with each participant's spectacle correction being worn. This method requires the use of a retinoscope, a near target, and a near point rod. For this study, an MEM target was used to keep the cognitive demand the same between each dynamic retinoscopy method. Data was collected again at distances of 40 centimeters, 33 centimeters, and 25 centimeters. In this procedure, the patient was asked to hold the near point rod to their forehead and then fixate on an age-appropriate MEM target located at each of the three working distances. In previous studies, it could not be ruled out that differences in findings were due to cognitive demand. As the subject attended to the target, the researcher used the retinoscope to view the horizontal meridian in the participant's right eye moving closer and farther from the participant until neutrality is determined. Data was then recorded for each of the three working distances.

For this station the distance at which neutrality was obtained was recorded, and then it was converted into the dioptric power. For example, if the neutral point was determined to be at a distance of 50 centimeters, then that was converted to the dioptric power of 2 diopters. For this example let's say the target was actually at a distance of 40 centimeters so the accommodative demand would be 2.5 diopters. After that the dioptric difference between the accommodative demand for that distance and the dioptric power of the subject's actual accommodation was recorded as the accommodative lag. Therefore, for this example it would be the difference between the participant's actual accommodative response of 2 diopters and the accommodative demand of 2.5 diopters, which would equal a lag of +0.50 diopters.

After data was collected for the 15 participants, it was analyzed.

CHAPTER 3
RESULTS

Accommodative lag measurements for the 15 test subjects were attained at three different working distances: 40 cm, 33 cm, and 25 cm test distance. The data being analyzed included all 15 test subjects, with all of them being deemed fit with intact binocular systems.

When first analyzing the findings, a comparative average found for accommodative lag at all three test distances for both the MEM and Nott measurements. These findings can be seen in Figure 1 with the general trend of accommodative response in relation to working distance as measured by MEM and Nott techniques.

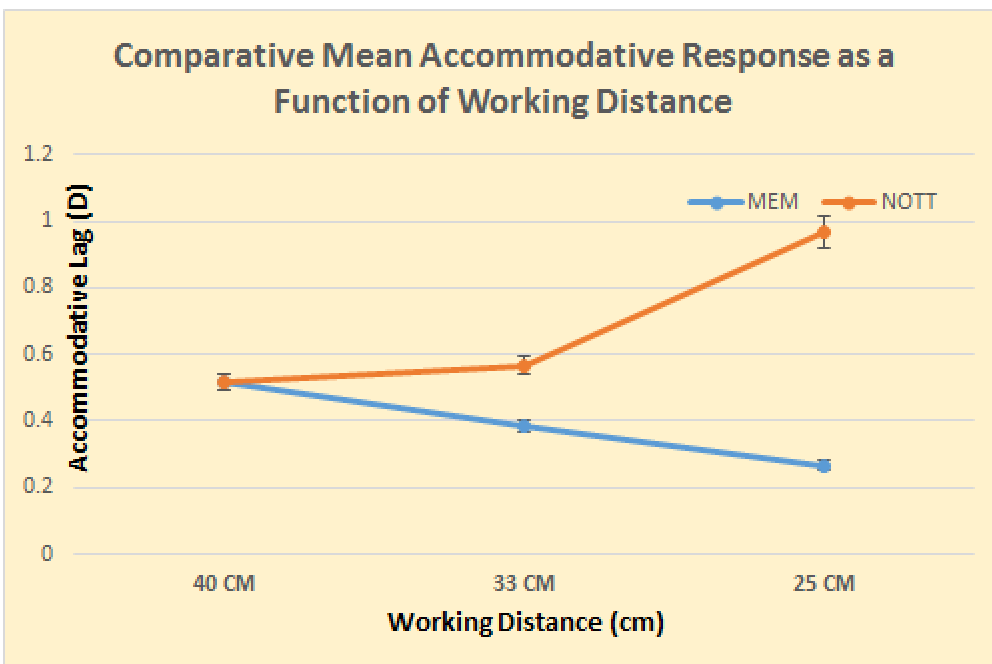

FIGURE 1

In assessing Figure 1, one can see contradicting accommodative response measurements between the two measuring techniques. In measuring with Nott retinoscopy, the accommodative lag shows an increase with shorter working distances. In other words, with objects being brought closer to the eye, the accommodative system response by allowing more "slack" to take place while maintain focus on the near object. In measuring with MEM, the opposite was found to be true. The accommodative lag was measured to be less as ones working distance became less. In other words, as an object is brought closer the accommodative response is to allow less "slack" to take place in order to maintain focus on a near object.

The expected normative values for accommodative lag lies within +0.25D and+0.75D for the classic working distance of 40 cm. For a lesser working distance such as 25 cm, normative values incorporates a wider normal accommodative range. A further breakdown of each measuring techniques was done for both MEM and Nott retinoscopy, showing the overall range of lag values. The variability in lag findings for MEM and Nott respectively can be seen in Figures 2 and 3 below.

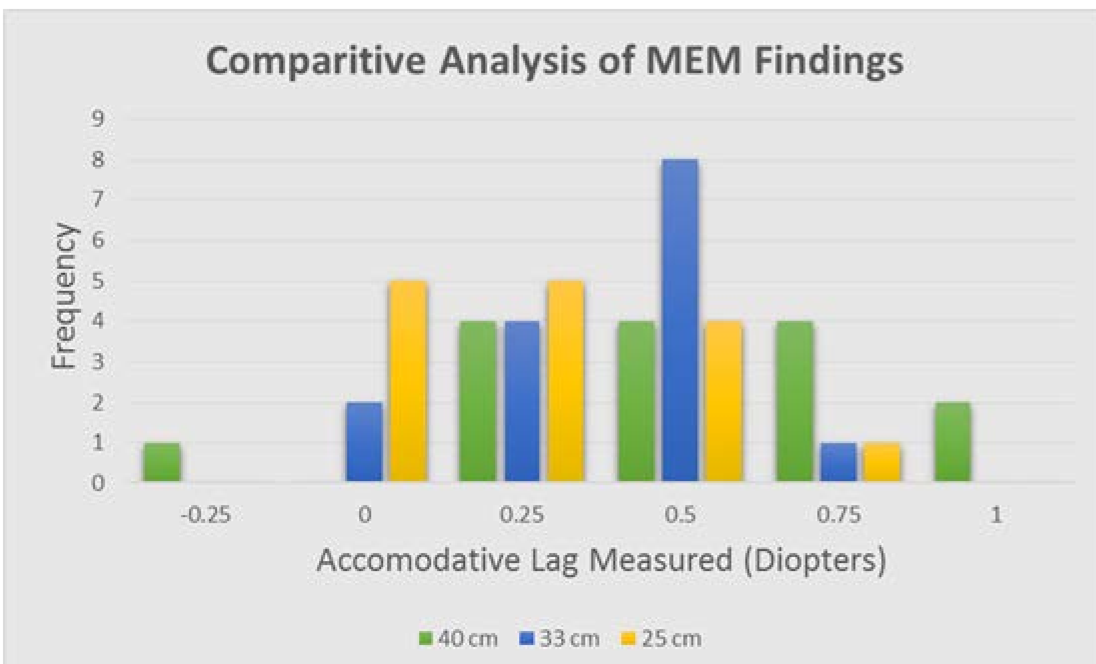

FIGURE 2

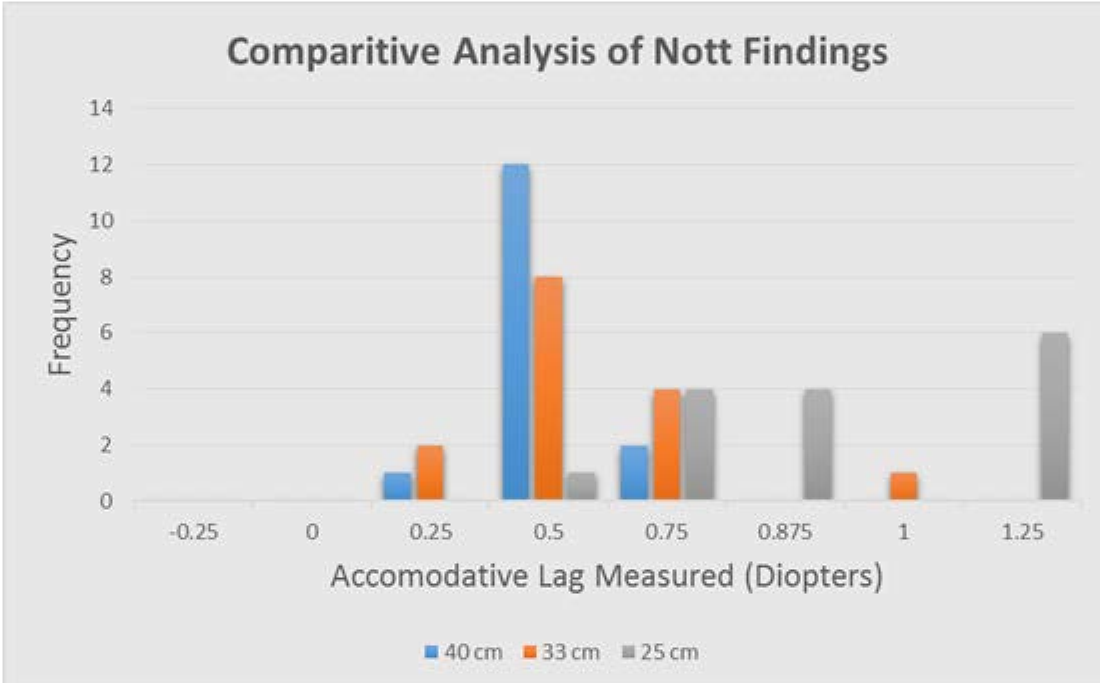

FIGURE 3

Both the Nott and MEM showed similar normative values for the 40 cm working distance, with Nott being found to be +0.517 +/- 0.114 and MEM being found to be +0.517 +/- 0.334. As the working distance became less, results for both MEM and Nott become more variable. The average lag Nott findings for 33 cm and 25 cm were +0.566 +/- 0.200 and +0.966 +/- 0.256 respectively, with the degree of variance increasing with decreasing working distance.

Analyzing the Nott measurements for all three working distance, a one way ANOVA was done to assess the relationship between the two. The results of this analysis were strongly significant [$F(2, 42) = 23.05$, $p < 1.75E^{-7}$]. This demonstrates that an increase in lag takes place with a decrease in working distance. This differs from a previous study performed in 2016 in which measurements taken with Nott retinoscopy showed no statistically significant change in relation to varying working distance in 56 test subjects.[5]

In contrast, the MEM measured lag showed a direct relationship between working distance and accommodative lag. The average MEM measured lag findings for 33 cm and 25 cm were +0.383 +/- 0.208 and +0.266 +/- 0.240 respectively, with the degree of variance also increasing with decreasing working distance. Analyzing the MEM measurements for all three working distances, a one way ANOVA was done to assess the relationship between the two. The statistically significant [F (2, 42)= 3.31, $p < 0.046$]. This relationship between working distance and measured lag opposes the Nott findings, but to a lesser amount statistically. This direct relationship between working distance and accommodative lag was also found to be true in the 2016 study of MEM.[5]

CHAPTER 4
DISCUSSION

There are several limitations with this study that could have affected the results. To start, the small sample size could have skewed the data one way or another. By having a larger sample size, the results obtained could be more reliable. Another limitation is that it is possible the participants may not have been in their most current prescription. For example, if they hadn't had an updated pair of glasses in five years because they are habitual contact lens wearers, or other such scenarios.

Possible limitations to this study could also be influenced based on error in measurement distance, particularly at the shorter working distance. If for instance the working distance at 25 cm was read (by either MEM method or Nott) at a 2 cm closer than intended, the amount of lag measured can be off by as much as +/-0.348 diopters. This same amount of error at the 40 cm test distance would only be off as high as +/-0.132 diopters.

The contradictions in measurements made between the two measurement techniques is surprising to say the least. One possible cause to the variability found in the measured working distance may come with MEM initiating a near response with a lens. MEM is supposed to be measured quickly with a loose lens being presented and withdrawn before the patient can adjust their focus. This proximal near response could be one possible explanation for variation in responses found between MEM and Nott. Other options as to the differences found is open to further investigation.

The findings of this study can have clinical implications as well. For one, a practitioner can start thinking about what distance is most appropriate to perform an accommodative lag at. It also may be helpful to consider what a patient is doing on a regular basis, for example if a patient is a software engineer and spends ten or more hours on the computer, it may be beneficial to determine what their lag is at their computer distance. Another aspect to think about is the normative lag at 40 cm is approximately +0.50 D, however there aren't any normative studies that could be found determining what the normative lag is at other distances. That information would also be helpful if practitioners are to start considering performing lag at different test distances.

In conclusion, this study did have statistically significant results that definitely have clinical implications. However, more research should be done, preferably with a larger sample size, to determine the repeatability of the data found.

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