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Pankhania, S.R. and Firth, A.Y. (2011) The Response AC/A Ratio: Differences Between Inducing and Relaxing Accommodation at Different Distances of Fixation. Strabismus, 19 (2). pp. 52-56. ISSN 0927-3972

https://doi.org/10.3109/09273972.2011.578192

Version date: 18.3.2011

THE RESPONSE AC/A RATIO: DIFFERENCES BETWEEN INDUCING AND RELAXING ACCOMMODATION AT DIFFERENT DISTANCES OF FIXATION

Running title: Response AC/A ratio

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Abstract

Purpose: To determine if there is a difference between the response AC/A ratios when measured using the gradient method at near and distance fixation with plus and minus lenses respectively in young adults with normal binocular single vision.

Methods: A repeated measures design was used. The accommodative response of the right eye was measured objectively using the Shin-Nippon SRW-5000 autorefractor [Grand Seiko Company, Fukuyama, Japan] (open view) at 33cm with and without plus lenses (2DS or 3DS) and at 3.8m with and without minus lenses (2DS or 3DS) dependent on the participants' ability to obtain subjectively 'clear' vision. The angle of deviation was measured using the alternate prism cover test at 33cm and 3.8m fixing with the right eye with the participant sat at the autorefractor. LogMAR 0.0 (6/6) was used for fixation. Response AC/A ratios were calculated.

Results: Twenty five participants were examined; mean and standard deviation of their ages were 21.2 ±4.04 years. The mean <u>and </u>~~(~~standard deviation~~)~~ of the near response AC/A ratios was 4.73~~/1~~±2.34~~)~~<u>/</u>~~:~~1 and at distance was 3.05~~/1~~±1.71<u>/1</u>~~)~~. Pearson's Product Moment Correlation Coefficient showed no correlation between the 2 sets of data. Paired t-test showed that there was a statistically significant difference between the near and distance response AC/A ratios ($t = 3.30$, $p = 0.003$). The difference was found to be greater in participants who were non-orthoptic students.

Conclusion: The response AC/A ratio was found to be slightly higher at 33cm with plus lenses than at 3.8m with minus lenses. No reason was identified for this difference but adaptation and perceptual effects could be further explored.

Key words: response accommodative convergence/accommodation (AC/A) ratio; accommodative lead; accommodative lag; accommodative response.

Introduction

The accommodative convergence to accommodation (AC/A) ratio is the ratio of the amount of convergence, measured in prism dioptres, to a given amount of accommodation. The stimulus AC/A ratio is usually assessed clinically and assumes that the change in accommodation occurring with viewing through a lens is equivalent to the strength of the lens. The response AC/A ratio takes into account the actual amount of accommodative change.

Under accommodation, or lag of accommodation, occurs either in free space or when the stimulus for accommodation is lens induced. The amount of lag is dependent on age and accommodative demand; in a student aged population, for 3D demand, it has been shown to be around 0.6D (Anderson et al., 2009). Conversely, when relaxation of accommodation is required, either from the resting point of accommodation or from the introduction of plus lenses at near, this relaxation is incomplete and results in a lead of accommodation, or over accommodation (Jiang et al., 2007). Wang and Cuiffreda (2006) state that 'the eye accommodates the minimum amount to place the target within it's depth of focus/field to see the object clearly.' Lags and leads of accommodation account for the differences found between the stimulus and response AC/A ratio.

Gage (1996) investigated the stimulus AC/A ratio in a group of students with normal binocular single vision using the gradient method on near and distance fixation with equal numbers of esophores and exophores. A significant difference in the near and distance AC/A ratios was found for exophores (medians 3:1 and 2:1 respectively). The response AC/A ratio is generally accepted as being higher than the stimulus AC/A ratio, due to the response of accommodation being lower than the stimulus. Gratton and Firth (2010) reported a response

AC/A of 2.43±1.60/1 compared to a stimulus AC/A ratio of 1.98±1.3/1 in young adults without strabismus.

The purpose of this study was to determine whether a difference existed between near and distance response AC/A ratios using the gradient method of measurement.

Materials and Methods

Thirty two students from the University of Sheffield were recruited for this study. The study was approved by the academic unit's ethics committee and in accordance with the Helsinki Declaration of 1995, the study was explained to all participants, an information sheet was given and written consent was obtained. Participants were told that the study was looking at how change in focus affects eye position.

The inclusion criteria were: normal binocular single vision and bifoveal fusion with at least 55 seconds of arc stereoacuity (Frisby near stereotest); visual acuity of at least 6/6 (logMAR 0.0) either eye corrected with contact lenses if necessary, and the ability to accommodate and relax accommodation by at least 2D with each eye monocularly at 3.8 m and 33cm respectively. To determine this, minus and plus lenses respectively were introduced in 1D steps and with each eye occluded in turn the participant asked if they were able to clear a 6/6 target at the appropriate distance. The time that this took was not measured but approximately 5 seconds was allowed. Whether a 2D or 3D lens was overcome was noted. Spectacles were not allowed due to the possibility of reflections of the infra-red beam from the autorefractor. Anybody with underlying ocular pathologies or a manifest strabismus was excluded from the study. A cover test was performed to ensure no manifest deviation was present and to identify the direction of any heterophoria.

The age, ethnicity, and refractive error of each participant were noted. The interpupillary distance (IPD) was measured using a millimetre scale to ensure accurate fitting of the trial frame. Counterbalancing was used ~~to reduce order effects and~~ to determine the order in which the refractive states of the right eye and the alternate prism cover test were carried out as well as the distance at which the measurements were to be taken.

All measurements were taken fixing with the right eye and maintaining full dissociation by occlusion at all times. All measurements were taken whilst the participant wore the trial frame and was seated behind a~~the~~ Shin-Nippon SRW-5000 autorefractor positioned 3.8m from a Bailey-Lovie logMAR chart. A Snellen stick was clamped into a holder at 33cms from the participant for near measurements. The back vertex distance on Shin-Nippon was set at zero. Participants were notified of the possibility of a slight headache following focussing through the lenses. Participants were asked at regular intervals if the target was clear: just before taking measurements of refractive state and on covering each eye during the prism cover test.

To measure the refractive state of the right eye, the left eye was occluded. The participant was instructed to fix on a 6/6 letter on a Snellen stick at 33cm for near measurements. The participant was warned that a beeping sound would be heard during testing as each measurement was taken (i.e as button pressed to record measurement). When the examiner was happy with the participant's eye position, 3 measurements of the refractive state of the eye were taken without any lens. The plus lens was then introduced in front of the right eye and making sure that the fixation target was still clear, 3 more measurements were taken. The Snellen stick was positioned directly in front of the participant's eye. Distance measurements were taken with the participant fixing on a 0.0 logMAR letter on a Bailey-Lovie chart at 3.8m. Initially, 3 measurements were taken without lenses and then a minus lens was introduced. After making sure that the target was clear, 3 more measurements were taken.

The fixation targets for the alternate prism cover test were again a 6/6 letter on a Snellen stick at near and a 0.0 logMAR letter on a Bailey-Lovie chart at 3.8m. As measurements of the angles of deviation were being taken fixing with the right eye, loose prisms were always held in front of the left eye and the movement of the left eye observed and neutralised with prisms. Measurements were taken with and without the plus lenses on near fixation, and minus lenses on distance fixation; always ensuring that the fixation target appeared clear. Each eye was occluded in turn and the prism strength was increased and reduced in 2Δ steps to neutralise the movement of the eyes.

The best representative value from the three valid measurements of refractive state of the right eye were noted. This value is given by the autorefractor (on print-out). It is not a mean of the readings, any reading in which, for example, a high cylinder has been given will be ignored. ~~The best representative values from the valid measurements of refractive state of the right eye, as given by the autorefractor, were noted.~~ From these values, the best spherical equivalents (BSE) were calculated (sphere + half cylinder) and used to calculate the change in accommodation for each fixation distance:

For near:

Change in accommodation = Absolute lens power – (BSE without lens - BSE with lens)

For Distance:

Change in accommodation = Absolute lens power – (BSE with lens-BSE without lens)

(where absolute lens power is the numerical power of lens without any sign).

The formula used to calculate the response AC/A ratio was:

$$\frac{[\text{Angle of deviation on accommodation} - \text{angle of deviation without accommodation}]}{\text{Change in accommodation}}$$

Statistical Analysis

Data were interval. Unpaired t-test or paired t-test were used to identify any differences and Mann Whitney where data were not normally distributed. Pearson's Product Moment Correlation Coefficients were calculated to examine correlation. A Bland Altman plot was also used for comparison. Three repeated measures ANOVAs were done to determine if any of the factors (type of refractive error, ethnicity, heterophoria) investigated had any influence on the findings from the study.

Results

Thirty two students were recruited but seven were excluded as they did not meet the inclusion criteria (six failed to meet the vision requirement and one was unable to relax accommodation by 2D at near). Of the 25 students that remained mean age (standard deviation, range) was: 21.2±4.04 (range 18-38 years), 22 were exophoric and three were orthophoric. There were five males and 20 females, 14 emmetropes, eight myopes,~~ and~~ two~~hree~~ hypermetropes and one astigmat. Twenty were orthoptic students.

The size of the near deviation ranged from 20PD to 0; and distance deviation from 10PD to 0. Median values at near for both orthoptic and non-orthoptic students were 6Δ, and at distance 2Δ for non-orthoptic students and 0 for orthoptic students. ~~.~~These baseline measures were not significantly different between orthoptic and non-orthoptic students (p=0.094~~142~~ and p=0.229~~0~~ respectively). Four of the non-orthoptic students were emmetropic and one myopic.

The mean ± ~~(~~SD~~)~~ response AC/A ratio for near fixation were 4.73 ±2.34/1 and the mean (SD) response AC/A ratio for distance fixation was 3.05±1.71/1. This difference was statistically significant (p = 0.003). The mean (SD) differences between the near and distance ratios for the orthoptic and non-orthoptic student participants were 1.09±2.34 and 4.07±2.02 respectively. This difference was significant (p=0.016).

No significant correlation was found between the data sets (r = 0.237, p =0.255) (figure 1). Bland Altman plot showed 95% limits of agreement of ±5 for AC/A ratio (figure 2).

Separate two factor analyses of variance did not show any significant interaction between distance and 1) type of refractive error (p=0.77); 2) ethnicity (p=0.87);, or 3) heterophoria (p=0.14), but power was low.

Discussion

The results of this study show that the response AC/A ratios when measured using the gradient method are generally higher for near fixation than distance fixation. Gage (1996) reported this same pattern in the stimulus AC/A ratios of exophores. Our participants were mainly exophoric. On the assumption that differences may have been due to lead or lag of accommodation during the measurement of stimulus AC/A ratios, it was expected that when the actual change in accommodation was used to calculate the AC/A ratio approximately equal response AC/A ratio values for both distances would be found. This was not so.

In this study artificial pupils were not used, nor was the pupil size measured. We would expect that pupil size was different for each refractive measurement, and could have affected the amount of lead or lag of accommodation, but as the actual change in refractive power of the eye was calculated with the addition of each lens this becomes irrelevant. The response AC/A ratio is calculated using the actual change in refractive status, i.e the actual change in accommodation.

None of the factors (ethnicity, heterophoria or refractive error) analysed were found to have any significant influence on the findings from the study. It has been suggested (Anderson et al., 2009; McBrien and Millodot, 1986) that the response AC/A ratios of myopes would be higher than that of hypermetropes and emmetropes due to increased accommodative lag with increasing stimulus levels. No evidence was found to support this, but there were only two hypermetropes in our study.

Rainey et al. (1998) showed 95% limits of agreement of ±3.6Δ for the prism cover test in a 'normal' population and so whilst this could explain some differences, it does not explain the size of the difference found here, nor the consistency of the effect being in the same direction.

Levels of adaptation can be different at different viewing distances and our results could be explained by the carry over of adaptation effects which also influence accommodative effect. It has been shown that adaptation to 6ΔBO and BI prisms does not affect the response AC/A ratio (Rainey, 2000) when measured at one distance (50cm); however Jiang and Ramamirtham (2005) found that by narrowing the interpupillary distance with an optical device and measuring the response AC/A ratio before and after 30 minutes of adaptation, the response AC/A ratio significantly reduced. Convergence accommodation has been shown to regress with vergence adaptation (Firth, 2008) and so it may be that the adaptive state at the start of our experiment affected the results. In patients with intermittent distance exotropia, this has been shown; following diagnostic occlusion the stimulus AC/A ratio reduces as the 'tenacious proximal fusion' is removed (Kushner, 1999). However, Horwood (personal communication, 2010) still found a difference in the near and distance response AC/A ratios in a group of intermittent exotropes following a period of occlusion and further study by ourselves of ten subjects (unpublished data) shows that a difference still exists in 'normals' following 25 mins of occlusion.

The Bland Altman plot showed a wide range in values (±5) and we regard this as beyond an acceptable difference for this clinical measure. This, together with the lack of a correlation between what is supposed to be two different methods of taking the same measurement, leads us to suggest that some other influences are occurring.

The change in target size due to the lenses was not taken into account in our study. Changing target size (looming) does have a very small effect on vergence (McLin et al., 1988). However, the perceived image size change during accommodation (accommodation micropsia) is 'mediated almost entirely by processes other than those involving the eye (Smith et al., 1992). Size constancy (in which a near target appears smaller than a distance target of the same angular size) may have an effect on our responses. The finding that naïve (i.e. non-orthoptic) participants showed a greater difference between the near and distance measurements does suggest that there is a perceptual influence; those who know what is happening are not so easily tricked but still show an effect, albeit reduced. It is now recognised that responses to accommodative and vergence stimuli ~~a~~can be~~re~~ different in naïve observers (Horwood and Riddell, 2010) compared with orthoptic and optometry students.

This study has shown that in a group of participants with normal binocular single vision; stimulation of accommodation with minus lenses on distance fixation results in a lower response AC/A ratio than with relaxation of accommodation with plus lenses at near. Participants in the study were exophores and orthophores. No reason was identified for the differences found between the near and distance response AC/A ratios.

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