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Stimulus and response AC/A ratios in an orthoptic student population

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Abstract

Aim: **To measure the stimulus and response AC/A ratios using the distance prism cover test gradient method in young adults without strabismus or ocular abnormality.**

Methods: **AC/A ratios were measured in a group of orthoptic students. The distance deviation (at 3.8 m) was measured with an alternate prism cover test using a Gulden prism bar with and without –3.00DS lenses. A Shin-Nippon SRW-5000 autorefractor [Grand Seiko Company, Fukuyama, Japan] (open view) was used to measure the refractive state with and without a –3.00DS lens. The stimulus and response AC/A ratios were calculated.**

Results: **Data were analysed for 16 participants. The mean and standard deviations (SD) of the distance stimulus gradient AC/A ratio were 1.98:1 (1.30) and the mean (SD) distance response gradient AC/A ratio were 2.43:1 (1.60). A paired *t*-test found a significant difference between the distance response and stimulus gradient AC/A ratio values ($t = 3.58$, $p = 0.003$). A Bland-Altman plot suggested that the difference increased as the size of AC/A ratio increased.**

Conclusion: **The response gradient AC/A ratio when measured using the prism cover test at a distance of 3.8 m was found to be higher than the stimulus AC/A ratio in a group of normal participants who were orthoptic students. This is due to the accommodative lag which normally occurs when viewing through minus lenses.**

Key words: Accommodative convergence/convergence (AC/A) ratio, Lag of accommodation

Introduction

The accommodative convergence/accommodation (AC/A) ratio measures the amount of convergence in prism dioptres which occurs with each dioptre of accommodation. Clinical measurements assume that the change in accommodation (i.e. the response) which occurs when viewing through a minus lens is equivalent to the power of the lens (i.e. stimulus). However, it has been shown that there is a lag of accommodation, such that the level of accommodation falls below that of the stimulus;[1] conversely when plus lenses are used at near there may be incomplete relaxation of accommodation (accommodative lead). Thus when the change of angle of deviation is divided by the actual change in accommodation (response), a higher value results.

Alpern *et al.*[2] state that the response AC/A ratio is about 8% larger than the stimulus AC/A. In strabismics, Miyata *et al.*[3] found that the response AC/A ratio was 41% greater than the stimulus AC/A ratio, suggesting that accommodative lag influences the distance gradient method of measuring the AC/A ratio.

The aim of this paper was to investigate the difference between the stimulus and response AC/A when measured with the distance prism cover test gradient method in normal young, non-presbyopic adults.

Methods

A repeated measures design was used. The study was approved by the Academic Unit's ethics committee. In compliance with the Helsinki Declaration, the main objectives and methods of the project were explained to all participants and an information sheet given. Written consent was obtained. Volunteers were recruited from an orthoptic student population.

Inclusion criteria were: best corrected visual acuity (contact lenses only) of 0.2 logMAR or better in either eye; no manifest strabismus; stereo-acuity of 110 seconds of arc or better (Frisby); and no presbyopia.

The inter-pupillary distance (IPD) was measured using a City rule, to allow accurate trial frame fitting. Participants were asked to choose one of two pieces of folded white plain paper to determine whether refractive state or prism cover test measurements were performed first. A 2 minute rest period between measurements was given. During this rest period participants were allowed to view normally with both eyes.

The first five participants were tested fixing the first letter on the 0.4 line of the Bailey-Lovie chart and the remaining participants were asked to fix the first letter on the 0.2 line.

To measure the refractive state of the eye with and without lenses the participant was sat behind the Shin-Nippon SRW-5000 autorefractor [Grand Seiko Company, Fukuyama, Japan] (positioned 3.8 m from a Bailey-Lovie logMAR chart) wearing trial frames with the left eye occluded. The participant was instructed to look at a letter on the Bailey-Lovie chart. The participant was warned that they might see a little red flash through

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the glass and might hear a bleeping noise, and that they should ignore these and keep looking at the letter. The participant's right eye was aligned on the autorefractor and three measurements were taken without a lens. A −3.00DS lens was then put into the trial frame of the right eye (with left eye occluded) and the participant asked whether the letter appeared to be clear. If it was not initially clear the examiner then instructed the participant to see whether they could make it clear. If they could not obtain a clear image, the lens was to be reduced in 0.50DS stages until the image was clear. The examiner aligned the right eye with the autorefractor while the participant fixated on the Bailey-Lovie logMAR chart and three measurements were taken through the minus lens for the right eye.

Measurement of the deviation was performed with the participant sat behind the autorefractor (positioned 3.8 m from the Bailey-Lovie logMAR chart) fixing a letter on the Bailey-Lovie logMAR chart. The moveable section of the autorefractor was pulled as far towards the examiner as possible to allow room for the examiner to perform a prism cover test measurement over the participant's trial frames. An alternate prism cover test measurement was taken without a lens. Lenses of −3.00DS were then placed in front of both eyes. The examiner covered one of the participant's eyes and asked whether the letter on the Bailey-Lovie chart appeared to be clear through the open field view from the autorefractor and through the −3.00DS lens. If it was not clear then the examiner instructed the participant to look hard at the letter and see whether they could make it clear. If the letter did not appear to be clear after this the lens was to be reduced in 0.50DS stages until it was clear. An alternate prism cover test measurement was then taken with the minus lens in place and the participant encouraged to maintain a clear image.

Participants' data were recorded on numbered participant record sheets to anonymise data. The best spherical equivalent (BSE) (sphere + half cylinder) was calculated from the best representative value of the three autorefractor readings.

The change in the refraction of the eye (accommodation) was calculated by:

$$\text{Strength of lens used} - (\text{BSE with lens} - \text{BSE without lens}).$$

The stimulus AC/A ratio was calculated by:

$$\frac{[\text{PCT } (^{\Delta}) \text{ with minus lens used} - \text{PCT } (^{\Delta}) \text{ without lens}]}{\text{Absolute power of lens}}.$$

The response AC/A ratio was calculated by:

$$\frac{[\text{PCT } (^{\Delta}) \text{ with minus lens used} - \text{PCT } (^{\Delta}) \text{ without lens}]}{\text{Absolute value of change in refraction of the eye}}.$$

Data were interval and a normal distribution was assumed. Statistical analysis was performed using SPSS 14 and StatView. Paired *t*-tests and analysis of variance were used to examine differences, and Pearson's correlation coefficient to examine linear relationship. A Bland-Altman plot was drawn to illustrate the differences between measures and the average of measures.

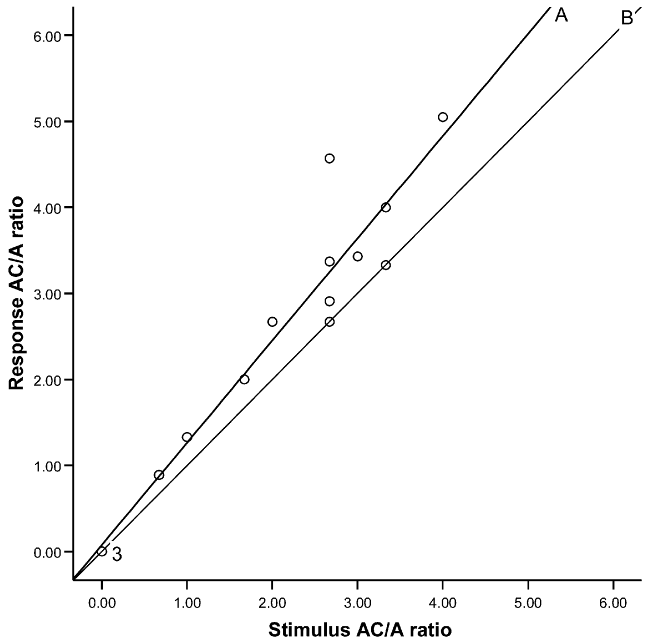

Fig. 1. Scatterplot of the distance response and stimulus gradient AC/A ratios ($^{\Delta}$ per 1 dioptre of actual or assumed accommodation respectively). *A*, line of best fit; *B*, 45° line (line on which values would fall if the same on both tests).

Results

Nineteen orthoptic students were recruited, but 3 were excluded as they did not appear to accommodate, but relaxed accommodation when viewing through minus lenses. For 2 of these 3 participants a −2.50DS lens had to be used. Of the 16 remaining participants (median age 19 years, range 18–38 years), 5 wore a myopic contact lens correction (range from −1.50DS to −7.50DS). At distance (3.8 m) 4 of the participants were exophoric (range 1^{Δ} to 8^{Δ}), 11 were orthophoric and 1 was esophoric. All 16 were tested using a −3.00DS lens and mean (SD) accommodative change was 2.45 (0.35)D.

The mean (SD) distance stimulus gradient AC/A ratio was 1.98:1 (1.30) (range 0–4) and the mean (SD) distance response gradient AC/A ratio was 2.43:1 (1.60) (range 0–5.05). A paired *t*-test found a significant difference between the response and stimulus AC/A ratio values ($t = 3.58$, $p = 0.003$). Statistical analysis using a two-factor ANOVA found no effect of target size on the AC/A ratios ($p = 0.169$).

A positive correlation ($r = 0.92$, $p < 0.002$) between the stimulus and response AC/A ratio measurement was present (Fig. 1). On a Bland-Altman plot (Fig. 2), all except one of the values lay within the 95% interval for agreement. The regression line of differences versus average shows that as the values increase, the difference increases.

The means and standard deviations for distance stimulus and response AC/A ratios for exophoric and orthophoric participants are shown in Table 1. The esophoric participant had a stimulus and response AC/A

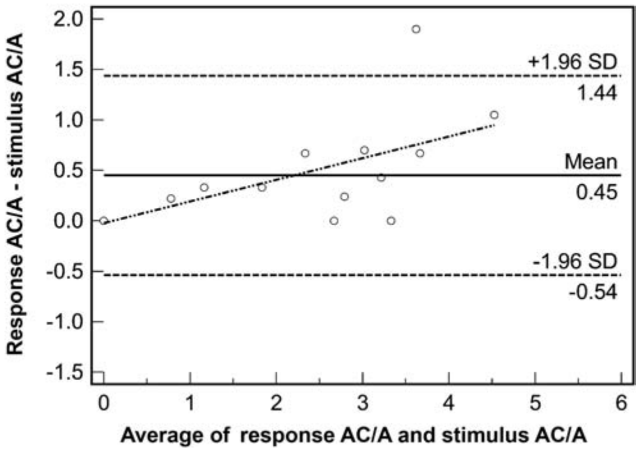

Fig. 2. Bland-Altman plot to show average and differences between response and stimulus AC/A ratios. The 95% confidence intervals of limits of agreement are shown, and the regression line of differences versus average.

Table 1. Summary of the mean distance stimulus and response gradient AC/A ratios for each type of heterophoria

Heterophoria type	Mean (SD) response gradient AC/A	Mean (SD) stimulus gradient AC/A
Exo ($n = 4$)	2.45 (2.23)	2.00 (1.83)
Ortho ($n = 11$)	2.56 (1.45)	2.09 (1.16)

ratio of 0.67:1 and 0.89:1, respectively. The mean (SD) distance response gradient AC/A ratio in myopic participants was 2.13:1 (2.15), and in emmetropes was 2.57:1 (1.38). The mean (SD) distance stimulus gradient AC/A ratio for myopic participants was 1.73:1 (1.74) and in emmetropic participants was 2.09:1 (1.13). Numbers were too low for meaningful statistical analysis.

Discussion

The results of this study show that the response AC/A ratio when measured by the prism cover test gradient method at 3.8 m is higher than the stimulus AC/A ratio in normal participants. This was the expected result and is explained by the accommodative lag which occurs when viewing through minus lenses. Alpern *et al.*[2] suggested multiplying the stimulus AC/A ratio by 1.08 to obtain the response AC/A ratio, but our results suggest a greater difference and that a multiplication factor of 1.23 would be more appropriate.

As would be predicted, a high correlation existed between the measures. The Bland-Altman plot is usually used to compare two methods of the same clinical measurement. Here, we acknowledge that we are comparing different tests, albeit related measures (response or stimulus AC/A ratios), but we have used the plot to look at the differences in the stimulus and response AC/A ratios, mainly with the purpose of showing that the differences, and variances, did increase with the size of the AC/A ratio.

Two different target sizes were used in this study and no significant effect on the results found; hence our participants were grouped into one data set. However, it is possible that a type 2 error has occurred here due to low power, and further study would be needed to confirm this finding.

The presence and type of heterophoria did not appear to have an effect on the response and stimulus gradient AC/A ratio results, nor did the presence of myopia. However, due to the low numbers involved in this study we do not feel a conclusion regarding these questions can be drawn from our data. Subbaram and Bullimore[4] found no difference in the accuracy of accommodation between myopic and emmetropic subjects and so perhaps we would not expect a difference to exist.

The finding that accommodative lag affects the distance stimulus and response gradient AC/A ratio, was also found in a similar study by Miyata *et al.*[3] using the prism cover test gradient method at 5 m. In a strabismic population the difference between the response and stimulus AC/A ratios was greater than in our non-strabismics. The mean (SD) stimulus AC/A ratio was 3.2(2.7):1 and the response AC/A ratio was 5.8(4.3):1. These standard deviations show variability in their data, which is not unexpected from a group of 63 patients with various types of strabismus. These authors also reported that exo deviations had larger lags of accommodation than eso deviations ($p = 0.002$). Similar to our findings, a significant correlation was present between response and stimulus AC/A ratios and the difference between measures increased with increasing ratios.

In our study the prism cover test measurements were taken under the same conditions as the measures of refraction and with normal pupil sizes. We did not measure the pupil size. Pupil size can affect the depth of focus and thus the lag of accommodation. It has been shown[5] that a larger variation between stimulus and response AC/A ratios occurs as pupil size is artificially reduced. The response AC/A remains the same, but the stimulus AC/A ratio reduces as pupil size is reduced because less accommodation is necessary to obtain a clear image due to the increased depth of focus when viewing through a small aperture ('pin-hole' effect). Under different conditions which affect pupil size, the differences, therefore, between the stimulus and response AC/A ratios could vary. Our measurements were taken in one session under room lighting with no natural light. We acknowledge that the level of accommodation could be affected by the awareness of the proximity of movement of the cover during prism cover test measurements, compared with the static cover when refractive measures were taken.

This study does have its limitations, as the procedure used did not reduce the effect of change in image size ('looming' or 'anti-looming') induced by negative lenses. Changes in image size can affect both accommodation and vergence.[6,7] The results may have been different had this been taken into consideration by altering the size of the fixation target so that it was equal with and without lenses, but this is not done clinically.

Horwood and Riddell[8] have reported that accommodative and vergence responses in 'naïve uninstructed participants' are most accurate when disparity cues are present, but that without disparity both are reduced and individual differences occur. It appears that the accommodative response to blur during monocular viewing was not what might be expected in our group of non-naïve participants either. The clinician needs to be aware that in a normal population the response to an accommodative stimulus and subsequent expected change in deviation cannot be assumed.

Conclusion

In a group of orthoptically normal participants, the response gradient method of measuring the AC/A ratio at a distance of 3.8 m using the prism cover test gave a higher value than the stimulus AC/A ratio in the region of 23%; this is due to the lag of accommodation which occurs when viewing through a minus lens. It is suggested that the difference varies slightly, with less difference for lower AC/A values and higher differences for higher values.

The authors have no competing interests.

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