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The Clinical Near Gradient Stimulus AC/A ratio correlates better with the response CA/C ratio than with the response AC/A ratio

Anna M Horwood, PhD [MRC Clinician Scientist Research Fellow] and Patricia M Riddell, DPhil [Reader in Developmental Neuroscience]

University of Reading

Abstract

Aim—To provide evidence that a near clinical gradient AC/A ratio could instead reflect the CA/C relationship (the accommodation driven by response to disparity)

Design—Case control study

Methodology—27 emmetropic participants with heterophoria <4PD, 19 with intermittent distance exotropia and 17 with near exophoria >6PD were tested. A remote haploscopic photorefractor which can measure simultaneous convergence and accommodation to a range of targets containing all combinations of presence or absence of binocular disparity, blur and proximal (looming) cues was used to assess response AC/A and CA/C relationships. These were compared with clinical gradient AC/A ratios at near and distance fixation using alternate prism cover test and plus or minus lenses

Results—Although the near and distance clinical AC/A ratios correlated weakly with each other ($p=0.03$), neither clinical method correlated with the more accurate response AC/A ratio from the laboratory method ($p=0.88$ & $p=0.93$). The laboratory CA/C ratio correlated strongly with the near clinical AC/A ratio ($p=0.004$) but only very weakly with the distance ratio ($p=0.16$).

Conclusions—The “near gradient AC/A ratio” may actually reflect the CA/C linkage as the dissociation of the prism cover test disrupts vergence accommodation. If the near deviation diverges more with plus lenses, it may be because the lenses allow clear near vision without needing to recruit convergence accommodation to achieve it.

Keywords

AC/A; CA/C; Exodeviation

INTRODUCTION

The near and distance gradient methods of assessing the AC/A (accommodative convergence to accommodation) ratio are said to be equivalent and can be used interchangeably e.g. (Ansons and Davis, 2001; Griffin and Grisham, 2002). In the near ratio, plus lenses are said to relax accommodation which then reduces accommodative

convergence, while the distance AC/A ratio induces accommodation through minus lenses and measures the increase of accommodative convergence. Both eliminate fusion by alternate occlusion, eliminate, or control for, proximal influences by standardizing the fixation distance and maximize accommodative accuracy by requiring subjective clarity of a detailed target. Differences between the near and distance gradient ratios have been reported using stimulus (Gage, 1996) and response methods (Pankhania and Firth, 2011), but not fully explained. Both are “stimulus” methods – assuming any accommodative stimulus causes equivalent actual accommodation, but accommodation inaccuracy (lag or lead) means that the divisor in the AC/A calculation is likely to be an inaccurate estimate (Ciuffreda and Kenyon, 1985; Gratton and Firth, 2010). “Response” methods, where vergence and accommodation are both measured, are more accurate and so are generally used in laboratory studies.

The role of vergence accommodation (the accommodation driven by response to disparity) is rarely considered, although research from labs where objective, naïve and naturalistic responses are measured suggests that disparity might contribute more to the global calculation of target position, and convergence *and* accommodation responses, than blur or proximal cues (Bharadwaj and Candy, 2009; Horwood and Riddell, 2008; Judge, 1996; Judge and Cumming, 1986). Although convergence and accommodation are usually strongly associated with each other, disparity can drive more accommodation than blur drives vergence, with the CA/C (convergence accommodation to convergence) linkage being more significant than the AC/A: “we accommodate because we converge” rather than vice versa.

There therefore might be an alternative explanation for the “near AC/A ratio” based on a “CA/C explanation”. The dissociation of the prism cover test removes disparity cues, which stops convergence and so reduces the accommodation response for near fixation. If clear vision is to be achieved monocularly for the pre-lens measurement, convergence may still be recruited to help drive the accommodation that is being stressed, so the true exodeviation fail to appear. The plus lenses used to test the ratio act as a near addition; they allow clear near vision without the need to accommodate, so convergence can relax maximally on dissociation as it no longer has to drive accommodation. We predicted that the poor reported correlations between the near and distance AC/A ratios may be due to the fact that the near “AC/A ratio” instead reflects aspects of the CA/C relationship.

METHODS

The study adhered to the Declaration of Helsinki and was allowed to proceed by UK NHS and institutional Ethics Committees. Three groups of participants were chosen to represent a wide range of AC/A ratios. 27 typically developing children between 5-9 years of age with heterophoria less than 6° at any distance, 19 similarly aged children with intermittent distance exotropias. These children were the subjects of studies reported recently (Horwood and Riddell, 2012a; Horwood and Riddell, 2012b). We also tested 17 naïve young adults and children with near exophorias greater than 6°.

Clinical near and distance stimulus AC/A ratios were assessed using a gradient prism cover test method after 30 minutes monocular occlusion, maintaining dissociation on removal of

the occlusion and throughout testing. The near test was carried out at 33cm using +3.0D lenses and the distance test was carried out at 6m using -3.0D lenses. Fixation targets used N5 point letters at 33cm and 0.1 logMAR letters at 6m. Extreme care was taken to ensure continued accommodation throughout testing by confirming image clarity before and after introduction of the lenses *and after every swap of the occluder*. 30% of the participants were unable to fully clear the fixation target using $\pm 3.00\text{D}$ lenses, in which case $\pm 2.00\text{D}$ lenses were used.

The laboratory method has been described in detail elsewhere (Horwood and Riddell, 2008), but briefly the participants viewed a target via a two-mirror optical system, while a PlusoptiXSO4 PowerRefII photorefractor collected simultaneous eye position and refraction measurements. (Fig. 1). Targets moved between five different fixation distances (0.33m, 2m, 0.25m¹, 1m, 0.5m) in a pseudo-random order.

We could manipulate blur, disparity and proximal (looming) cues separately. Blur cues could be presented by using a detailed clown target containing detail down to 1 pixel (<1min arc) or minimized by using a blurry difference of Gaussian (DoG) image to maximally open the accommodation loop while retaining fusible features when testing binocularly. Disparity cues were available when both eyes viewed the target, and could be eliminated by occluding half the upper mirror (C in Fig. 1), so that the target was then only visible to one eye. Proximal and looming cues were available when the target remained the same size on the screen and could be watched as it moved backwards and forwards, or could be minimized by scaling the target so that it subtended the same retinal angle at each distance and hiding the screen from view as it moved with a black curtain.

We calculated dioptres of accommodation (D) and meter angles of vergence (MA) from the raw refraction and eye position data, making individual corrections for measured angle lambda and inter-pupillary distances (IPD). By using MA we were able to compare simultaneous vergence and accommodation responses in relation to target demand much more accurately between participants with different IPDs and also plot both on the same scales e.g. a 0.5m target demands 2D of accommodation and 2MA of vergence.

In this study we considered accommodation and vergence responses in relation to target demand to four of the eight possible targets conditions:-

- a) Naturalistic, all-cue. The unscaled binocular detailed (clown) target.
- b) Occluded. The same clown target under monocular conditions, to examine how excluding disparity affected accommodation, but still retaining proximal cues.
- c) Blur-only. The above monocular clown target was then scaled and screened between fixation distances, minimizing proximal cues so presenting blur cues in isolation. The response AC/A ratio was calculated from the difference between vergence responses to this blur-only cue between the 2m and 33cm fixation distances divided by the simultaneous accommodation response change.

¹The data from this target position were discarded for technical reasons not associated with the study

- d) Disparity-only. Here we used the scaled DoG target under binocular conditions. The CA/C ratio was calculated from the difference between accommodation at 2m and 33cm divided by actual change in simultaneous vergence.

Clinical AC/A ratios were also converted from prism diopters per diopter (Δ :D) to MA:D by correcting for differences in IPD between individuals so that laboratory and clinical tests could be compared. A 0.67MA:1D is equivalent to a typical 4 Δ :1D ratio in an adult with a 6cm IPD. A matrix of Pearson's correlation coefficients was calculated for the different measures of AC/A and CA/C ratio using SPSS v18.

RESULTS

Accommodation lag was typical in the laboratory, with a mean lag at 33cm of 0.31D (10%) to the all-cue target. Eliminating disparity cues reduced accommodation at 33cm by a further mean 0.9D (to lag of 1.21D), with no statistically significant differences between the response reduction across the three diagnostic groups. The additional elimination of proximal looming cues made very small and non-significant difference to the responses ($p>0.2$ in all comparisons involving the whole group or different diagnosis categories). Ratios are shown in Table 1. High CA/C ratios were common, with disparity-only cue frequently driving as much accommodation as vergence. There was wide variability (note wide 95% confidence intervals), especially for the laboratory response AC/A ratios. A very small change in accommodation could accompany a large change of vergence so lead to a high AC/A ratio, (or very occasionally vice versa leading to a low ratio).

Near and distance clinical AC/A ratios correlated positively but only weakly ($r=0.29$, $p=0.03$) with each other. No clinical AC/A ratio correlated significantly with any objective response laboratory AC/A ratio. (Table 2)

By far the strongest correlation in this disparate set of data was between the near clinical AC/A ratio and the laboratory objective CA/C ratio ($r=0.38$, $p=0.004$).

DISCUSSION

Clinicians know that and a "high" clinical stimulus ratio is rarely precisely repeatable. In this study correlation between the very careful near and distance clinical AC/A ratios, as well as response and stimulus AC/A ratios, was poor or non-existent. This is well known in the literature (Gratton and Firth, 2010; Havertape et al., 1999; Murray and Newsham, 2010; Rainey et al., 1998), even in highly controlled laboratory studies using trained participants; serving to illustrate the limitations of clinical methods. Accommodative lag (which is much greater when monocular, as we have shown) means that any clinical AC/A ratio which does not measure accommodation can only give a rough estimate of the "true" response ratio, where vergence and accommodation are both measured.

The strongest and most significant association found was between the laboratory response CA/C ratio, and the near clinical stimulus AC/A ratio. This suggests that the near "AC/A" ratio might instead be reflecting accommodative response to change in vergence cues, rather than vergence response to blur cues, explaining the poor near/distance AC/A correlation.

We suggest that an explanation for these study findings could be that the dissociation of the near prism cover test removes the stimulus to convergence, which then causes secondary loss of accommodation. The convergence cannot relax too far, otherwise the target would blur (which is being actively discouraged by the tester). If any conscious control is involved, convergence may also be being positively recruited via voluntary input in order to drive accommodation (Maxwell et al., 2012). The plus lenses used for testing the near AC/A ratio may not primarily relax accommodation via the AC/A ratio; they may just allow convergence to relax further because it does not need to be retained to maintain accommodation.

Accommodation and convergence generally co-vary, and each can be driven by the other, but our work has shown us the limitations of even the response AC/A and CA/C ratios if tested in isolation. They tell us whether blur only drives accommodation (low AC/A) or disparity only drives vergence (low CA/C), whether each drive can both to an extent (higher, typical ratios), or whether blur drives excessive vergence (abnormally high AC/A) or disparity drives excessive accommodation (abnormally high CA/C). The higher the ratio, the more manipulating one (for example with lenses or dissociation) affects the other.

But a further question should be asked. Which cue (blur or disparity) is stronger to tell the individual where the target is in space so that vergence and accommodation can be initiated? The response CA/C and AC/A ratios alone cannot fully answer this question; e.g. a $-3.0D$ lens may drive $1D$ of accommodation and $0.66MA$ of vergence in one child and $3D$ of accommodation and $2MA$ of vergence in another; both have a “normal” response AC/A ratio of 0.6 (approx. $4 : 1D$), but the second child is clearly more responsive to blur cues.

So how useful is any clinical AC/A ratio? High AC/A ratios are uncommon in typical populations while high CA/C ratios seem more typical. However inaccurate, a high clinical AC/A ratio may be a useful indication that blur cues may be driving vergence when most typical individuals prefer to use disparity to drive both vergence and accommodation.

If the near clinical AC/A ratio reflects the CA/C relationship, does it leave the distance AC/A ratio our best clinical estimate of the “true” AC/A relationship? In the distance clinical AC/A ratio the potential for dissociation of the prism cover test to reduce accommodation is more limited as it is relaxed anyway, so accommodation before and after dissociation will be similar. The patient is then asked to clear the image through lenses, so they can only use the blur cues presented. We feel that the conventional accommodative vergence mechanism is likely to apply here and so the test does roughly estimate the true AC/A ratio, although we still cannot totally exclude the possibility that convergence is recruited first to drive the accommodation even in this position, as suggested recently (Maxwell et al., 2012). The weak, non-significant association we found between the distance clinical AC/A and the lab CA/C is still stronger than that of either clinical AC/A ratios with the lab AC/A ratio.

Studies of response latency of vergence and accommodation would help explore this hypothesis further; if disparity (and CA/C) are the primary cues, then vergence onset might

precede accommodation, while if blur and AC/A are the primary drive onset of accommodation might precede vergence.

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Figure 1.

The remote haploscopic videorefractor. (A) Motorized beam. (B) Target monitor. (C) Upper concave mirror. (D) Lower concave mirror. (E) Infra-red 'hot' mirror. (F) Image of participant's eye where occlusion takes place. (G) Plusoptix SO4 PowerRef II. (H) Headrest. (J) Raisable black cloth screen. Clown and difference of Gaussian targets illustrated lower right; much of the high resolution detail of the clown has been lost in this reduced reproduction.

Table 1

Clinical and laboratory AC/A and CA/C ratios

	Mean	95% CI
Clinical Near Stimulus AC/A	0.50 MA:D (approx. 2.8 :D)	0.38-0.62
Clinical Distance Stimulus AC/A	0.49 MA:D (approx. 1.28 :D)	0.32-0.67
Lab response AC/A	0.64 MA:D (approx. 3.6 :D)	0.02-1.27
Lab response CA/C	1.27 D:MA (approx. 0.22D:)	1.0-1.54

Stimulus and response AC/A and CA/C ratios. Meter angles used as units so participants with different IPD could be compared with maximum accuracy. Approximate prism diopter values based on group means.

Table 2

Pearson correlation matrix of clinical and laboratory AC/A and CA/C ratios

	Clinical Near AC/A	Clinical Distance AC/A	Lab blur-only cue vergence change / accom change (Lab AC/A)	Lab disparity-only cue accom change / vergence change (Lab CA/C)
Clinical Near AC/A		0.29 p=0.03*	-0.013 p=0.925	0.38 p=0.004**
Clinical Distance AC/A			0.02 p=0.88	0.19 p=0.16
Lab blur-only cue vergence change / accom. change (Lab AC/A)				-0.026 p=0.85
Lab disparity-only cue accom. change / vergence change (Lab CA/C)				

Asterisks denote statistical significance