The fixation target influences the near deviation and AC/A ratio in intermittent exotropia

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PURPOSE	Divergence excess intermittent exotropia is thought to comprise 2 types of deviation, simulated and true. It is believed that simulated divergence excess is akin to a basic deviation but is controlled at near through accommodative and adaptive fusional vergences. While fixation target detail is known to influence accommodation and subsequently deviation size, no previous study has investigated the effect of the fixation target on the AC/A ratio in intermittent exotropia and its influence on the deviation's classification.
METHOD	Twenty-five participants with intermittent exotropia underwent near and distance measurement before and after 45 minutes of occlusion. The near angle was also measured through +3.00 D lenses, and using 2 different sized targets, an N60-equivalent "butterfly" picture and N5 print. The gradient AC/A ratio was calculated for each target.
RESULTS	There was a significant difference between the measurements using the 2 targets, $t(24) = 8.3$, $p \leq <0.001$. On average, the near angle was 8.8^Δ greater using the N5 print. This also resulted in a significant difference for the AC/A ratio, $t(24) = -8.4$, $p < 0.001$, the mean with the target being 3.6^Δ:1D, as compared to 6.6^Δ:1D with the N5 print.
CONCLUSIONS	Through careful control of accommodation by ensuring relaxation with plus lenses to clear N5 print, we revealed increases in the AC/A ratio and unmasked deviations that would otherwise have been considered to be characteristic of true divergence excess. Simulated and true deviations are possibly part of a continuum and clinical delineation may be influenced by testing artefact. (J AAPOS 2010;14:25-30)

The classification and subsequent management of divergence excess type intermittent exotropia rely on the outcomes of clinical testing that aims to suspend "adaptive" fusional and/or accommodative vergences—the very mechanisms by which the deviation may be controlled at near. Intermittent exotropia has most notably been classified by Burian and Franceschetti[1,2] and later by Kushner.[3,4] Burian and Franceschetti[1,2] subdivided intermittent exotropia into true divergence excess and simulated, whereby patients with the simulated type demonstrate an increased near angle after monocular occlusion of 30-45 minutes or with convex lenses, while those with the true type do not demonstrate either. Kushner[3,4] further subdivided the simulated condition into 3 types, taking into consideration the AC/A ratio pre- and postocclusion (Table 1).

Given the importance of the AC/A ratio measurement in the classification of intermittent exotropia, its clinical measurement must be regimented. Previous studies have established the gradient method to be the most accurate.[5-8] Studies have also indicated that monocular occlusion is required prior to measurement of the AC/A ratio[4,5,9] due to adaptive fusional vergence effects, commonly referred to as "tenacious proximal fusion" or "fusional vergence aftereffect," contaminating the measurement.[4,9] However, the AC/A ratio is influenced not only by the presence of tenacious proximal fusion but also by a patient's accommodative response to lenses during testing. The purpose of using plus or minus lenses in measuring the AC/A ratio is to, relax or induce accommodation and the related accommodative convergence, respectively. When testing the stimulus AC/A ratio, it is assumed—perhaps hoped—that the accommodative response is equal to the stimulus presented. The assumption ought to be reconsidered, however. Studies that have objectively measured accommodation have found mismatches to commonly occur between a patient's accommodative response and with presented stimuli (plus or minus lenses).[9-12] This assumption, when violated, can significantly affect the outcome, grossly underestimating the AC/A ratio. When testing the stimulus AC/A, as is done clinically, one must therefore make every effort to ensure that the patient has relaxed or induced accommodation appropriately through the

Table 1. Subdivision of simulated divergence excess intermittent exotropia

Type	Cause of near/distance disparity
Normal AC/A ratio with tenacious proximal fusion	Tenacious proximal fusion
Normal AC/A with tenacious proximal fusion and a pseudo high AC/A ratio*	Tenacious proximal fusion
High AC/A ratio without tenacious proximal fusion	High AC/A ratio

*AC/A ratio high when measured prior to occlusion but normal when measured after occlusion.

stimulus provided. The patient must at least demonstrate maintained visual acuity while viewing through the lenses. A patient able to read the smallest test type through lenses has invariably had an appropriate change to their accommodation.

Target size and detail are well known to affect accommodation, such that a patient is not required to change accommodation to identify, for instance, a large target as compared to a fine, detailed target. It has also been demonstrated that using different accommodative fixation targets produces different measurements in patients with an intermittent exotropia or partially accommodative esotropia.[13] In the case of intermittent exotropia, the purpose of fine detailed targets is to control over-accommodation rather than to stimulate accommodation. Despite the importance of ensuring appropriate accommodation during measurement of the AC/A ratio, to our knowledge no study has investigated the effect of target size on the AC/A measurement. Our study aimed to investigate the influence of 2 commonly used but different fixation targets with different accommodative demand on the AC/A ratio measurement in patients with intermittent exotropia and their influence on the classification of patients' deviations.

Subjects and Methods

This study was approved by the Faculty Human Ethics Committee, La Trobe University, and by the respective committees of the Royal Children's Hospital and Northern Health. Twenty-five participants (*n* = 25), aged 4.8-15.9 years (mean, 9.9 ± 3.2 SD), were included. All were patients attending the Royal Children's Hospital, Northern Hospital, Melbourne Children's Eye Clinic, or La Trobe University Orthoptic Clinic. They were invited to participate if they had a documented intermittent exotropia of the divergence excess type, and although strict age limits were not set, only those who were deemed to have suitable cooperation for testing were included. This was determined at the time of recruitment. Those who could not demonstrate relaxation of accommodation during testing were excluded. If a patient could not identify the N5 optotypes with convex lenses, this was considered a sign of their inability to relax their accommodation appropriately. Those with any other ocular or neurological pathology were also excluded. No participant was undergoing orthoptic

treatment for intermittent exotropia (such as minus lens therapy or occlusion) at the time of enrollment. Three participants previously had bilateral lateral rectus recessions.

Intermittent exotropia was defined as an exodeviation that displayed phases of heterophoria and heterotropia during examination. Traditionally, intermittent exotropia where the deviation at 6 m exceeded that at 1/3 m by 10^Δ is considered as divergence excess.[1,14-17] There were 19 such participants as well as 1 who had a 10^Δ difference between their measurement at >6 m and 1/3 m and 5 others who had a significant increase in their distance angle relative to that at near (although not by 10^Δ; their deviations were at least double at 6 m than at 1/3 m). These 5 participants were included, as they not only showed an increase in their deviation at 6 m but also demonstrated control of the exotropia at 1/3 m, where adaptive fusional and/or accommodative vergences play a role.

Participants underwent an orthoptic assessment including visual acuity and ocular motility testing. Visual acuity was assessed using a logMAR chart at 6 m with refractive correction as appropriate. All participants had undergone a cycloplegic refraction within 6 months of testing. Cover testing was used to determine the ocular alignment at 1/3 m, 6 m, and >6 m; a prism cover test was used to measure the deviation at the 3 distances. The prism cover tests were performed at near using N5 optotype on a fixation stick, at 6 m using the smallest letters correctly identified on the logMAR chart, and at >6 m with the participant instructed to look either outside a window or down a corridor at objects approximately 15 m distant.

After the initial orthoptic assessment, each participant underwent 45 minutes of monocular occlusion of the eye seen to deviate most frequently during testing. Following occlusion, the deviation was again measured at the 3 distances, ensuring dissociation so the participant was not allowed to regain fusion. Similarly the AC/A ratio determination was made after the occlusion period.

To calculate the (gradient) AC/A ratio, each participant's deviation was also measured at 1/3 m using +3.00 D lenses in trial frames. In 1 participant +2.50 lenses were used due to their inability to identify the N5 print with +3.00 D lenses. This was performed after the 45 minutes of occlusion. Two fixation targets at 1/3 m were used for testing: (1) a picture of a butterfly on a fixation stick, the image measuring 1.1 cm horizontally and 0.7 cm vertically, with the visual angle approximating N60 print; and (2) N5 print on a reading card (Figure 1). Although the targets differed in that one presents a single picture and the other a set of N5 letters, they were chosen because they are commonly used cover test targets in the clinical setting and reflect not only a difference in size but also the difference between using targets that promote sustained change in accommodation and those that do not. It is accepted that once a target is recognized and identified it can potentially lose its hold on accommodation. By using N5 print, sustained accommodation could be ensured and then compared to a target that could not bring about appropriate relaxation of accommodation during testing.

The butterfly target was always presented first to avoid contamination of results. If the participant was initially tested with the N5 target, it is possible that they would maintain their relaxed accommodation when subsequently tested with the butterfly. We

FIG 1. Image of butterfly and N5 fixation targets. For the N5 target participants were asked to continually identify the words and letters on the N5 line.

FIG 2. Distribution of AC/A ratio using the butterfly and N5 target.

Table 2. The mean angle of deviation at 1/3, 6, and >6 m before occlusion and after monocular occlusion using the N5 target

Distance	Before occlusion Mean (SD)	After occlusion Mean (SD)
1/3 m	6.9^Δ (± 5.9)	16.0^Δ (± 8.7)
6 m	21.6^Δ (± 6.3)	24.0^Δ (± 8.8)
>6 m	25.5^Δ (± 9.3)	26.9^Δ (± 9.4)

felt that controlling for this effect outweighed any benefit of randomization. Measurements were taken when the participant was able to identify the butterfly or read the N5 print for the respective targets.

The AC/A ratio was determined using the gradient method, as described in Anson and Davis' text.[14] For each participant, 2 calculations were made—one for the butterfly and one for the N5 print. We used a revised range of normal AC/A ratio (being between 2^Δ and 4.9^Δ:1 D) to categorize the AC/A ratio as being low, normal, or high.[5]

Results

Group Characteristics

All 25 participants had unaided or best-corrected visual acuity of 6/9.5 or better in each eye. None had greater than a line's difference between the 2 eyes. Only 1 wore refractive correction (for low myopia). None had clinically significant hypermetropia defined as greater than 2 D of spherical equivalence on cycloplegic refraction. Of the 25, 3 had previous strabismus surgery (bilateral lateral rectus recessions) for intermittent exotropia; all of these had near-distance differences of between 8^Δ and 12^Δ; 1 demonstrated a high AC/A ratio.

Size of Deviation

Table 2 summarizes the mean angle of deviation measured at the 3 distances before and after occlusion. The mean angle at 1/3 m and 6 m increased after occlusion, which was the case in all but 1 participant; this increase being statistically significant, $t(24) = 7.2$ $p < 0.001$ and $t(24) = 2.3$, $p = 0.03$, for both distances, respectively. The mean angle at
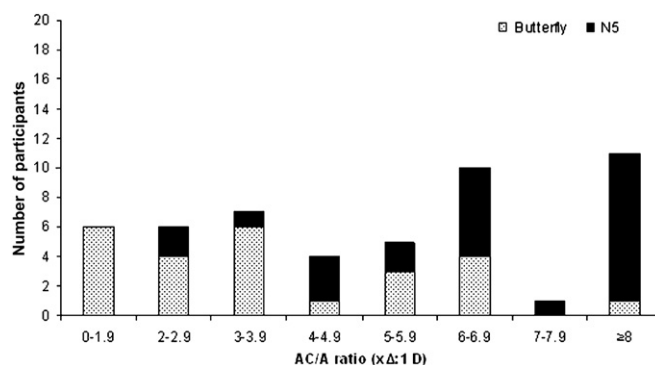
>6 m before and after occlusion failed to reach a significant difference, $t(24) = 1.8$, $p = 0.08$.

The mean exodeviation measured with the N5 print was 35.6^Δ (SD $\pm$ 10.8), and with the butterfly 26.8^Δ (SD $\pm$ 10.6), the difference being statistically significant, $t(24) = 8.3$, $p < 0.001$.

AC/A Ratio

The mean AC/A ratio using the N5 print was 6.6^Δ:1 D (SD $\pm$ 2.1^Δ), compared to 3.6^Δ:1 D with the butterfly (SD $\pm$ 2.1). This difference was statistically significant, $t(24) = -8.4$, $p < 0.001$.

The distribution of the AC/A ratio also differed with the 2 targets (Figure 2). Using the butterfly, the majority (68%) of AC/A ratio measurements were $\leq 4.9^\Delta$:1D. In contrast, relatively few (24%) were $\leq 4.9^\Delta$:1 D with the N5 print. Conversely, only 32% ($n = 8$) of participants had a high AC/A ratio ($\geq 5^\Delta$:1 D) with the butterfly, this increasing to 76% ($n = 19$) with the N5 target. With the N5 print, in fact, no participant had a low AC/A ratio ($< 2^\Delta$:1 D).

Further, when comparing the AC/A ratio as measured with the butterfly and N5 targets, 56% ($n = 14$) of participants shifted to a higher category of AC/A ratio when measured with the N5 print (Table 3).

Classification of Intermittent Exotropia

A total of 20 participants demonstrated a divergence excess type intermittent exotropia whereby the angle differed by at least 10^Δ from 1/3 m and 6 m or >6 m. The 5 other participants had an increase in the distance of up to 8^Δ or 100% from 1/3 m to 6 m. For the purpose of this article, all 25 participants were considered to have an intermittent exotropia of the divergence excess type. There was no statistically significant difference between the mean AC/A ratio measured between these 2 groups, $t(23) = -1.178$, $p = 0.251$.

Of the 25 participants, 21 were classified as simulated and 4 as true when using the butterfly fixation target. With the N5 print, however, these 4 were reclassified as having the simulated type of deviation. For these 4 participants, the mean distance-near difference was 17^Δ (SD $\pm$ 4.6^Δ) and the mean AC/A ratio was 8.1^Δ:1 D (SD $\pm$ 0.6^Δ).

Table 3. Number of participants changing AC/A ratio category

Category change	Number of participants
No change	11 (44%)
Low to normal	2 (8%)
Low to high	3 (12%)
Normal to high	9 (36%)

None of these 4 had undergone previous strabismus surgery.

Discussion

The assessment of the AC/A ratio in a patient with intermittent exotropia of the divergence excess type is integral to understanding the mechanism by which the exotropia is controlled at near and classifying the deviation. Furthermore, the management and/or surgical procedure of choice are often based on the subcategorization of intermittent exotropia and the presence or absence of a high AC/A ratio. Our study aimed to investigate the effect of the fixation target size on the AC/A ratio measurement in intermittent exotropia and its influence on the classification of the deviation.

We found that target size had a significant effect on the angle of deviation measured through convex lenses. Compared to the butterfly target, the N5 print elicited a larger exodeviation in all but 1 participant. On average, the angle measured with the N5 print was greater by 8.8^{Δ}. In effect, the amount of accommodation relaxed when the N5 print was greater than with the butterfly target, and hence, the accommodative relaxation response better corresponded to the stimulus. Because the butterfly subtended a visual angle approximating N60, this seemed not to require by visual necessity full relaxation of accommodation to identify the picture. Patients with intermittent exotropia are well known to over-accommodate to maintain ocular alignment; this over-accommodation in turn results in a reduction of visual acuity.[18] The butterfly target provided little incentive to release this accommodation. Furthermore, the use of a single butterfly, rather than a series of pictures, also ensured that participants were less likely to relax their accommodation after identifying the target, allowing us to better compare the effect of accommodation on the AC/A ratio. However, it is also worth noting that the lack of randomization in our study could have potentially influenced the results. Given that the N5 target was always presented later, prolonged alternate cover test (first with the butterfly and then the N5 target) may have disrupted binocularly yielding a greater deviation with the second target. Nonetheless, we felt that introducing the N5 target first was a greater risk, as it could potentially contaminate the response to the butterfly.

The issue of accommodative mismatch has been reported in previous studies that have measured accommodation objectively. Schnider and colleagues[19] measured the accommodative responses in patients with intermittent exotropia and found that these patients had difficulty in relaxing their accommodation compared to normal subjects. Hasebe et al[10] also found that mismatches occurred between accommodation and presented stimuli in patients with intermittent exotropia. Similarly, Rosenfield and Carrel[12] reported that the higher powered plus lenses caused significant amounts of accommodation to remain unrelaxed when they measured accommodative responses.

Table 4. Previous studies reporting the incidence of high AC/A ratio in intermittent exotropia of the divergence excess type

Study	AC/A ratio considered to be high	Percentage of exotropes with high AC/A ratio
Smith (1986)[22]	$>5^{\Delta}$:1 D	47.1%
Kushner (1988)[3]	$>6^{\Delta}$:1 D	9%
Plenty (1988)[16]	Not stated	AC/A ratio was higher in patients with exotropia
Kushner and Morton (1998)[4]	$>6^{\Delta}$:1 D	5%
Kushner (1999)[8]	$>6^{\Delta}$:1 D	7.2%
Arnoldi (2006)[5]	$>5^{\Delta}$:1 D	21%

The increased angle of deviation with the N5 print had a corresponding effect on the AC/A ratio calculation. With the butterfly target, we found fewer participants (19%) had a high AC/A ratio. These results are in keeping with Kushner's, because most of his participants had low to normal AC/A ratios. However, with the N5 print, a shift occurred whereby most participants (76%) had a high AC/A ratio. Even if we had used Kushner's more rigorous definition of "high," this being $\geq6^{\Delta}$:1 D, 68% of our participants would still have demonstrated a high AC/A ratio. This is considerably higher than the 5%,[4] 7.2%,[8] and 9%[3] reported by Kushner as having high AC/A ratios in his studies and similarly higher than the 21% reported by Arnoldi and Reynolds.[5]

The proportion of patients with a high AC/A ratio who have intermittent exotropia of the divergence excess type has often been debated (Table 4).[3-5,8] A possible reason for the difference between our findings and those studies[3-5,8] (which report that only a minority of patients demonstrate a high AC/A ratio) could lie in the testing method. None of these studies reported fixation target size specifications and whether a single or series of targets was used during testing and may have been overlooked. However, given that most clinicians are aware of the impact of accommodative and nonaccommodative targets on strabismus measurements,[13,20] it is also unlikely that these studies did not try to control accommodation at near. There are also a number of methods to measure the AC/A ratio, namely, the heterophoria and gradient method before and after occlusion, some of which can result in a pseudo-high AC/A ratio. However, the utilization of minus lenses in the distance pre- or postocclusion and of plus lenses at near after occlusion (as used in our study) are considered qualitatively the same, yielding the most accurate AC/A ratio.[8] It is therefore unlikely that the gradient method used in our study resulted in pseudo-high AC/A ratios but rather that the target used influenced the outcome.

It should also be noted that after occlusion the near measurement without convex lenses was performed with N5 optotypes, meaning that the AC/A ratio calculated for the butterfly target used an N5 measurement without lenses. While it could be argued that had we used the same target to measure the AC/A ratio for the butterfly a more accurate AC/A may have been determined, we do not believe this to be the case. Given that the AC/A determination relies on dividing the difference between the size of the deviation during 2 accommodative states by the power of the stimulus, one of the most important aspects of the AC/A determination is the participant's ability to match their accommodation to the stimulus. That is, if the butterfly target was used with and without lenses and the mismatch in accommodation between these 2 states was equal, the AC/A ratio would still be underestimated as we would be dividing by the power of the stimulus, which was not achieved by the participant.

It could also be argued that the accommodative tone produced while fixing on the N5 target without lenses may have been carried into the next test where the participant was asked to fix on the butterfly target through lenses. However, we were particularly interested in the participants' ability to relax accommodation using various targets. Clarity of the target ensures that the relaxation of accommodation has been achieved. Had the N5 target been used first with lenses, identification of the optotypes would have resulted in the release of any accommodative tone remaining from the previous test, again potentially contaminating the butterfly response.

Kushner,[3,4,8] Cooper and colleagues,[9] and Arnoldi and Reynolds[5] have suggested that adaptive fusional vergence ("tenacious proximal fusion" or "fusional vergence aftereffect") plays a more significant role in reducing the size of the deviation at near than a patient's accommodative convergence. This is supported by the clinical finding that many patients with a high AC/A ratio do not develop a postoperative consecutive near esotropia. However, although some studies[21] suggest that a consecutive near esotropia is uncommon in patients with a high AC/A ratio, others[8] have reported contradictory findings.

Although patients classified as having simulated intermittent exotropia of the divergence excess type do not always develop a consecutive near esotropia, this does not necessarily refute reports[16,17,22] of high incidences of high AC/A ratios in intermittent exotropia patients, such as in our study. There is evidence that the AC/A ratio is somewhat "elastic" and changeable, where the functions of convergence and accommodation have a certain degree of independence from each other.[23] This elastic relationship has been described through processes of relative convergence (convergence is stimulated in excess of accommodation) and relative accommodation (accommodation is stimulated in excess of convergence). The dissociation of these 2 functions is the basis of orthoptic treatment for certain types of accommodative esotropia.[14,23] Studies have also shown that the AC/A ratio is changed through surgery,[24,25] drugs,[14,26] and orthoptic treatment.[14,27] In Kushner's[8] study, two-thirds of patients with a high AC/A ratio who were treated with minus lenses showed "normalization" of their AC/A ratio. It is possible that patients with intermittent exotropia who show a high AC/A ratio actually reduce their AC/A ratio postoperatively because they no longer require the excessive accommodative convergence to maintain fusion at near. This would explain the low incidence of postoperative consecutive near esotropia.

Our results indicate that high AC/A ratio is a feature of divergence excess type intermittent exotropia; however, this does not deny the role of "tenacious proximal fusion" in maintaining binocularity at near. Measurements taken at 1/3 m before and after occlusion significantly differed. While occlusion increased the near angle, this was still less than that of the distance angle. Kushner[3] reported that "tenacious proximal fusion" was responsible for masking most patients' near deviations and that a high AC/A ratio only occurs relatively infrequently and as an isolated finding. However, we propose that more likely an interplay exists between these two mechanisms. Using Kushner's subdivision of simulated divergence excess type intermittent exotropia, a quarter of our participants did not fit into any of Kushner's 3 subclassifications. They displayed both "tenacious proximal fusion" and a high AC/A ratio, highlighting possible coexistence of the two. It appears that the 2 mechanisms can work together, with some participants utilizing more adaptive fusional vergence at near than accommodative convergence and others conversely relying on accommodative convergence more so.

Our quest to explore the mechanism by which a patient controls their near deviation is an important part of classifying intermittent exotropia into simulated or true types. We have found that the target size used to measure a patient's AC/A ratio can result in incorrect classification of an intermittent exotropia. A total of 12 participants had a categorical shift in their AC/A ratio from low or normal to high when using the N5 print, 4 of whom were also reclassified from originally true to simulated divergence excess.

Although we did not objectively measure accommodation in this study and cannot guarantee that the patients' accommodative response precisely matched the stimulus presented, we have shown that choice of target can affect the AC/A ratio determination and therefore influence classification of a patient's intermittent exotropia. We further suggest that the suspension of adaptive fusional vergence and accommodative convergence may be more difficult in some patients, thus making simulated divergence excess deviations appear as if they were true. It is also possible that true divergence excess exotropia may be a testing artefact whereby the suspension of adaptive mechanisms is not always achieved in the clinical setting. Rather than distinct entities, the simulated and true deviations are possibly part of a continuum that presents as intermittent exotropia of the divergence excess type. We suggest, based on our findings, using an accommodative target size of N5 and

preferably print to evaluate patients with apparent divergence excess type intermittent exotropia through convex lenses.

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