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Title: Test-Retest Reproducibility of Accommodative Facility Measures in an Unselected Sample of UK Primary-School Children

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Running title: Accommodative facility in primary-school children

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Background: To determine the test-retest reproducibility of accommodation facility (AF) measures in an unselected sample of UK, primary-school children.

Methods: Using ±2.00DS flippers and a viewing distance of 40cm, AF was measured in 136 children (range 4-12 years, average 8.1±2.1) by five testers on three occasions (average interval between successive tests: 8 days, range 1–21 days). On each occasion, AF was measured monocularly and binocularly, for two minutes. Full data sets were obtained in 111 children (81.6%).

Results: Intra-individual variation in AF was large (SD=3.8cpm) and there was variation due to the identity of the tester (SD=1.6cpm). On average, AF was greater (i) in monocular compared to binocular testing (by 1.4cpm, p<0.001), (ii) in the second minute of testing compared to the first (by 1.3cpm, p<0.001), (iii) in older compared to younger children (e.g. accommodation facility for 4/5 year-olds was 3.3cpm lower than in 10+ year old children, p=0.009) and (iv) on subsequent testing occasions (e.g. visit-2 accommodation facility was 2.0cpm higher than visit-1 accommodation facility, p<0.001). After the 1st minute of testing on visit-1, only 36.9% of children exceeded published normative values for accommodation facility (≥11cpm monocularly & ≥8cpm binocularly), but this rose to 83.8% after the third test. Using less stringent pass criteria (≥6cpm monocularly & ≥3cpm binocularly), the equivalent figures were 82.9% and 96.4%, respectively.

Conclusions: The results reveal considerable intra-individual variability in raw AF measures in children. When the results are considered as pass/fail, children who initially exhibit normal AF continued to do so on repeat testing. Conversely, the vast majority of children with initially-reduced AF exhibit normal performance on repeat testing. Using established pass/fail criteria, the prevalence of persistently reduced AF in this sample is 3.6%. Reduced AF not co-exist with abnormal near-point of accommodation or reduced visual acuity.

Accommodation enables the eye to bring objects placed at different distances into focus, and in humans, accommodative function can be measured clinically in a variety of ways [1-3]. As well as the maximum accommodation which can be exerted, clinicians can assess the accuracy of accommodation and the accommodative facility. The latter refers to the speed with which accommodation can be engaged and disengaged, and is the subject of the present investigation. Accommodation facility (AF) is of interest to clinicians because poor performance on this task may be associated with reading performance in children[4-6], because infacility can exist independently of other accommodative anomalies[2] and because AF measures may allow symptomatic and asymptomatic individuals to be distinguished[7,8]. There is also evidence that reduced AF is prevalent, even in children[9,10] and that when it exists, it responds well to treatment[11-14].

Many factors affect the AF result, including whether measures are taken monocularly or binocularly [15-17], the lens powers used in testing, the target size and the viewing distance[18-22]. Some authors have advocated using lens powers which stress a fixed proportion of the individual's amplitude of accommodation[21]. Thus, using this approach, higher lens powers are used in younger patients.

A weakness of the clinical measurement of AF relates to the fact that the practitioner must rely upon the subjective response of the patient. Aside from vergence movements and perhaps changes in pupil size, both of which are associated with the engagement and then the relaxation of accommodation, there is no objective information available to the clinician to indicate that the patient understands and is complying with the AF task requirements. Thus the quality of the instructions given by the examiner is crucial, and this may be particularly important in young children, because the concepts of 'blurred' and 'clear' are not easy to explain or to grasp.

There are other factors which are also likely to exert a particular influence upon AF measurement in young children. One is the manner employed to have the patient subjectively indicate that the target has, following the introduction or removal of the stimulus to accommodation, again become clear. In some cases, the patient indicates the target has become clear simply by saying 'now' whereas in others, the patient is required to actually call out what they see (e.g. by reading numbers aloud, [23]). Cognitive factors again come play here because the rapid identification of letters or numbers may be too challenging for young children, depending on their learning. Another cognitive factor affecting AF measurement in all patients, though perhaps particularly in young children, relates to the speed with which blur can be identified and then reported. Thus there are many factors which may contribute to the repeatability of the AF measurement, and these factors may particularly apply in children.

This study examines the reproducibility of AF measures in an unselected sample of primary-school children when tested by different examiners. The aims are to determine the variability of AF measurement and how, using established pass/fail criteria, the proportion of children who pass and fail the test varies with repeat testing.

METHODS

The study was approved by the University of Bradford Ethics Committee and was conducted in accordance with the Declaration of Helsinki of 1975.

Data were gathered at two schools from an unselected sample of children; by 'unselected', children were not excluded because of any current or previous ocular condition and other than the use of spectacles, the researchers had no prior knowledge of the children's current or past ocular health. LogMAR visual acuity, stereopsis and near point of accommodation were measured. The stereopsis[24] and near point of accommodation[25] results have been previously published. There was no opportunity to determine or, where necessary correct, the refractive error prior to gathering these clinical measures.

Children viewed N5 text, with glasses if worn, that was held by the tester at 40cm and they were asked if it was seen clearly. If not, the smallest size text that was reported as 'clear' was used. Accommodative facility was tested using +2.00DS/-2.00DS lens flippers. One cycle consists of the participant reporting the text to be clear, firstly through the -2.00DS lens and then the +2.00DS lens. When lenses were introduced, participants were asked to report as soon the print became as clear as it was prior to the introduction of the lens. During monocular measures, the eye not under test was covered by a translucent occluder.

A short practice was given to each participant to try to improve understanding of the procedure. The number of cycles per minute achieved was then recorded for a period of two, one-minute periods which ran continuously[16,17]. The children were tested on three separate occasions (average interval between successive tests: 8 days, range 1–21 days) by five unqualified examiners. Each examiner was trained and supervised by one of the authors (PA) and observed on at least their first two assessments. The proportions of the data gathered by the different examiners were: 36%, 28%, 15%, 13% and 8%. On repeat testing, measures were not gathered at the same time of day in individual children, owing to practical aspects of accessing the children during the school day. At the first visit, the following order of testing was employed; visual acuity was measured initially, followed by stereopsis measurement[24]. Next, there followed either near point of accommodation (NPA) or accommodative facility measures. The order of this testing (NPA or AF) and the order in which measures were to be taken (right, left or both eyes) was read from a table of random numbers. On subsequent testing occasions, visual acuity was not measured. Stereopsis was measured first, followed NPA or AF, as in the first visit.

Overall, 31% of the children were tested by different examiners on each occasion, 55% had the same examiner on two occasions and 14% had the same examiner on all three occasions. On the second and third tests, examiners had no access to previous AF measurements. Testing was conducted in large rooms which were well lit from natural and artificial sources. Participants' details are shown in Table 1. Based upon a criterion for normality of visual acuity (with glasses if worn) of 0.20 logMAR or better in each eye, 86% (117/136) of the entire sample had 'normal' visual acuity. Twenty children (14.4%) wore glasses during testing and 111/136 (81.6%) were tested three times (13.2% were tested twice; 5.1% were tested only once).

[Insert Table 1 about here]

RESULTS

Effect of Tester

There was a highly significant effect of tester identity on AF (p<0.001). The average AF for Tester 1 in the first minute was 7.2 cycles-per-minute (cpm), whereas the values measured by Testers 2, 3, 4 and 5 differed relative to Tester 1 by an average of +2.4cpm, +1.4cpm, +4.3cpm and +3.9cpm, respectively (all p<0.001). For this reason, all of the subsequent analyses took account of this systematic effect of tester identity by incorporating tester identity as a random effect.

Regression Analysis

There was no significant difference in AF measures between boys and girls (p=0.31) or between the AF measures taken in the two schools (p=0.25). AF measures did not differ in the right and left eyes (p=0.24). Gender and school were therefore dropped from the model. A repeated measures, random-effects regression model was employed. This model accounts for within-subject correlations, thus enabling us to retain data from right and left eyes from individual participants. A statistically significant (p<0.001) difference was found between the AF in the first and second minute. A mixed-model regression analysis using raw AF measures was employed. In addition to examining the effect of visit, viewing condition (monocular versus binocular), test duration (minute 1 versus minute 2) and age group, the analysis employed searched for an interaction between age-group and the change in AF in the 2^{nd} minute of testing relative to that exhibited in the first minute. This was driven by the clinical question of whether it is important to continue measurement of AF into a second minute in some age groups but not others.

Similar to AF test results in adults[7], repeat testing of AF led to higher measures; the AF on the second and third testing occasions were higher compared to the AF at visit one by 2.0cpm and 2.9cpm, respectively (both p<0.001) (Table 2). On average, binocular AF measures were lower than monocular measures by 1.4cpm (p<0.001) and the confidence interval indicates the uncertainty in this estimate (i.e. the true value is very likely to lie between 1.1 and 1.8cpm) (Table 2). AF measures from the second minute were 1.3cpm higher than those from the first minute of testing (p<0.001) (Table 2). In relation to age, the youngest participants (4 & 5 year-olds) had significantly lower AF measures than 6 and 7 year children (average difference 3.8cpm, p=0.001) and 10+ year-old children (average difference 3.3cpm, p=0.009). The estimated mean difference between 8/9 year olds and 4/5 year olds was 2.0cpm, which was not statistically significant (p=0.09) (Table 2).

The mean increase from minute one to minute two was largest for the 4/5 year olds (1.3cpm). The average increase was only 0.8 in the 6/7 year olds, and only 0.2cpm for 8/9 year olds. Similarly the average increase from minute one to minute two in the 10+ age group was 0.3cpm. Only the latter two interaction terms were statistically significant (p=0.023 and p=0.044, respectively) (Table 2).

[Insert Table 2 about here]

Intra- and Inter- Subject Variation and Variation due to Tester

There was moderate between-tester variation (standard deviation[SD]=1.6cpm). Thus, the variation due to the identity of the tester was such that taking account of visit, and all other factors (e.g. monocular versus monocular), around 68% (1SD) of AF measures taken by different testers were within 1.6cpm of each other. This level of variation due to tester applies across all age-groups. The between-subject (SD=4.0cpm) and the within-subject (SD=3.8cpm) variation were similar to one another (Table 2). The fact that within-subject variation is almost as large as the between-subject variation obviously highlights large within-subject variability. It is worth pointing out that there is a degree of heteroscedasticity in the relationship (not shown) between the residuals and the fitted values from the regression modelling, with the residuals exhibiting less scatter at lower AF values. Thus the intra- and inter-subject variations are lower than the values quoted above when the AF values are low, but are larger for higher AF values.

Effect of Visual Status

When the modelling described above was re-run including only the children classified as visually normal (logMAR visual acuity better than 0.20 in both eyes), a very similar pattern of results was obtained concerning the effect of visit and age. The average within-child (3.7cpm) and between-child (3.9cpm) AF variations are also similar to the corresponding values for the full data set. When the definition of visually ‘normal’ was extended to include not only visual acuity better than 0.2logMAR in both eyes but also monocular and binocular NPA values of less than 9cms, the average within-child (3.7cpm) and between-child (4.0cpm) were again similar to the corresponding values for the full data set.

AF and reproducibility of AF from a clinical perspective

Therepeated-measures logistic regression model was re-run with the data coded as ‘pass’ or ‘fail’ using criteria of ≥11cpm monocularly and ≥8cpm binocularly [15,26] (Table 3). The pattern of results obtained is very similar to the model for raw AF measures presented in Table 2. Compared to visit 1, the likelihood of a ‘pass’ was increased at visit 2 compared to visit 1 (odds ratio =exp (0.4)=1.5) and further increased at visit 3 (odds ratio= exp(1.2)=3.3). On average, binocular testing of AF is more likely to yield a 'pass' (odds ratio=2.5) compared to monocular testing, and continuing testing into a 2nd minute also increases the likelihood of a 'pass' (odds ratio=2.2) (Table 3). As with the modelling of the raw AF measures, the probability of a pass was greater in older compared to the youngest children ($p<0.05$ for comparisons of 4/5 year olds with all three other age-groups). Table 3 also reveals the same trend for age-group by minute-2 interaction that was evident in Table 2 but the effects were weaker and mostly not statistically significant. This study is underpowered to detect interaction terms when using a binary outcome measure (Table 3). The model was also run using less stringent pass/fail criteria (≥6cpm monocularly & ≥3cpm binocularly)[16,17,27], however this model failed to provide a description of the data due to ceiling effects because over 80% of children achieve a 'pass' during the first minute on the first testing occasion (Table 4).

[Insert Tables 3 & 4 about here]

The effect of continuing testing into a second minute and across visits is further studied in Table 4 which shows the proportion of children who pass at minute 1 on visit-1 using the two pass/fail criteria described above. These criteria are referred to in the literature as 'high-fail' (≥11cpm monocularly and ≥8cpm binocularly) and 'low-fail' (≥6cpm monocularly & ≥3cpm binocularly)[15-17,26,27]. Table 4 shows the cumulative proportion of children who exhibit a 'pass' as testing continues into a second minute and across subsequent visits.

For the 'high fail' criterion, only 36.9% pass at the end of the first minute of testing at visit 1 but this increases to 58.6% by continuing into the second minute of testing. Following testing on the second and third occasion, the proportion of children who 'passed' increased to 70.3% and 83.8%, respectively. Thus, using this criterion, 16.2% of children were found to have persistently reduced AF (Table 4).

For the less stringent ('low fail') criterion, 82.9% passed after the first minute on the first occasion of testing. This jumped to 90.1% by continuing into the second minute and then to 96.4% after the second test. There was no increase from visit 2 to visit 3, meaning that, using this criterion, 3.6% of children were found to have persistently reduced AF (Table 3), a value which accords well with values in the literature (see Discussion). Interestingly, the likelihood that a normal result will be obtained in subsequent testing appears to depend greatly on whether the AF result in the first minute is a 'low fail' or a 'high fail'. For example, for AF results for the first minute that are classed as 'low fails', <5% become passes when the measurement is continued into a second minute. However, when the AF result from the first minute is a 'high fail', 60-65% of the AF measures become passes in minute 2.

In the same way that children who exhibit a ‘fail’ on initial testing frequently exhibit a ‘pass’ when testing is continued into a second minute or when testing is repeated on a subsequent occasion, the analysis employed examined whether the frequency with which children who ‘pass’ in the first visit demonstrate reduced AF on later testing occasions. Of 92 children who passed the using the ‘low-fail’ criterion on the first testing occasion and for whom full AF datasets were available, only 8 (8.7%) demonstrated a ‘fail’ using the same criterion on either of the subsequent testing occasions. None of these children exhibited persistently reduced AF at visits 2 and 3, but rather they showed single, isolated (monocularly or binocularly) reduced AF which was not consistent with the results from the first occasion of testing representing a false negative. Thus when normal AF performance is exhibited on initial testing, the chances of a subsequently discovered AF problem seem remote, but the same is not true in reverse; when an abnormal AF is initially exhibited, it is more than likely that the result will become normal on subsequent testing.

Agreement between visual acuity, near point accommodation and accommodative facility results

Near point accommodation (NPA) for this sample have already been published[25]. Here, an investigation was conducted as to whether those children who exhibited, across all three visits, an NPA of 9cms or above in monocular or binocular testing also exhibited persistently reduced AF. Also, the frequency with which persistently reduced AF existed amongst children with normal NPA was examined. The results of this analysis indicated no association between poor performance on these two measures of accommodation. Of the 104 children with full AF and NPA datasets, 12 (11.5%) were found to have persistently abnormal NPA values, none of whom had persistently reduced AF using the ‘low-fail’ criterion. Visual acuity was also normal (<0.20 logMAR in the two eyes) in all twelve children. Also, only 2 of the 104 children (2%) exhibited persistently reduced AF and neither showed abnormal NPA. One of these two children had reduced visual acuity. Thirteen of the 104 children with full datasets (12.5%) had reduced visual acuity whilst exhibiting normal AF and normal NPA scores.

DISCUSSION

The AF measures reported here compare well with previous studies of AF in unselected or asymptomatic samples of children[6,8,10]. For example, mean monocular and binocular AF values are 12.7±5.6cpm and 11.6±5.6cpm, respectively, in this sample aged 4-12 years. This compares to values of 11±4cpm and 10±4cpm, respectively, reported in 7-12 year olds[10], and to 12.8±1.9cpm and 9.0±3.5cpm in 6-14 year-olds[6]. Lower average values (5.5-7cpm monocularly,3-5cpm binocularly) for AF have been reported[23] but these data were gathered using a specially-designed instrument and a testing approach which required the children to name the numbers they saw rather than simply indicating that the target being viewed was clear.

Interestingly, however, the values quoted by Scheiman et al [23] represent extremely useful cut-offs (see below).

The results also reveal marked intra-individual variation when AF testing is repeated. Indeed the within-subject variation is only marginally smaller that the variation exhibited between individuals (Table 2). This raises questions about the usefulness of the test in children. Given the subjective nature of the test, the variation due to the tester that these results reveal may indicate differences in level of understanding, or in the rapport between the practitioner and patient, when children are tested by different examiners.

It is believed that this is the first study to highlight how the identity of the tester can impact on the AF measured in children. The variation in AF measures associated with the identity of the tester is moderate (SD=1.6cpm) and this is likely to reflect, at least in part, the fact that the testers in this study were not clinically qualified (see *limitations* below). It might be expected that the inter-examiner variation in AF measures would have been less if the data were gathered by experienced practitioners.

Consistent with a previous study[23], the AF data in the present study show a small but significant increase with age in children (Table 2). Whether this reflects an actual improvement in AF with age or merely reflects a greater understanding of the task requirements or expectations by older children is unknown. It is also possible that marginally poorer AF in younger children reflects slower processing speed However, given that there was an increase on repeat testing just a few days later, the data presented here would appear to support the view that reduced AF in the youngest children arises from poorer understanding of the task requirements or expectations compared to older children . Improvements in other measures of visual function with repeat testing over the same, brief time period have previously been reported in this sample[24,25].

In clinical settings, practitioners who include the AF test in their assessment will not use the test in isolation but as part of a battery of tests to try to arrive at a diagnosis. With AF measures, as with other clinical vision measures (e.g. accommodation[25] or stereopsis[24]), practitioners may rely less upon the raw test result, preferring instead to interpret the result as a ‘pass’ or a ‘fail’. Relative to average AF values[15,17,27], the results show that on repeat testing, the chances of obtaining a test result that exceeds the criterion value for a ‘pass’ increase markedly. McKenzie et al [27], using a similar approach, reported that the proportion of children passing increased from 53.8% on the first test, to 69.2% and then 83.1% on the second and third tests, respectively. Conversely, the results indicate that a normal AF result on initial testing is very unlikely to mask the presence of actual AF problem that is revealed through further subsequent testing.

One very important factor influencing the likelihood of a fail result becoming a ‘pass’ on subsequent testing concerns the level of the fail. Children with ‘high’ fails (>6cpm but <11cpm monocularly; (>3cpm but <8cpm binocularly) are very likely to exhibit a pass if the testing is continued into a second minute, or if not, on repeat testing (Table 4). However, children with ‘low’ fails (<6cpm monocularly; <3cpm binocularly) on initial testing are much less likely to achieve a pass on subsequent testing. This pattern of results from repeat testing has previously been observed [16,17,27]. For example, for binocular AF measures[17], both 'low fail' and 'high fail' groups improved with additional testing time but the average improvement was greater for the 'high-fail' group; furthermore, after 3 minutes testing, 40% of the high-fails had passed, whereas none of the low-fails had passed. In the equivalent study of monocular AF[16], an average improvement of 1-2cpm was found when testing continued into a second and third minute. Over the 3 minute testing period, 73.3% of the 'low fails' remained as 'low fails' but 43.4% of the 'high fails' reached the 'pass' criterion. Overall therefore, the results suggest that AF measurement is most valuable when it yields a low result, meeting the criterion for a 'low fail' because this may reflect a genuinely low facility. Using this cut-off, 3.6% of this sample had persistently reduced AF. This prevalence estimate for accommodative infacility is broadly similar with estimates from some other studies (e.g. 1.5%,[28]). Reduced AF in the present sample did not co-exist with abnormal NPA or reduced visual acuity.

This study has a number of significant limitations. One is that the measures of binocular AF gathered here did not include a suppression check as recommended[23]. Since other clinical visual data were gathered prior to measuring AF (visual acuity, stereopsis[24] and, in some children, near point of accommodation[25] measures, see methods), a limitation is that the AF measures may have been affected by fatigue or reduced co-operation caused by the testing which preceded AF measurement. Another limitation is that the testers were not clinically qualified, although they did receive training in how to gather the measures and they were observed by a clinically-qualified individual (author PA) until they were deemed to be competent. This significance of this potential limitation is unknown because there is little objective information available to the clinician during the test. However, the variation in AF results between testers is of concern (Table 2) and it is not known to what extent this variability would differ if the testers had been clinically qualified. Another significant limitation is the fact that refractive error was not determined prior to gathering the AF measures. This represents a departure from how this test is used in clinical practice and it will, in some children, have contributed to larger variability than might otherwise have been observed. Also, during binocular AF testing, children were not asked to distinguish between situations where the text was seen clearly but doubled versus clear and single. Thus some of the binocular AF failures may in fact have been due to a binocular vision disorder rather than to an accommodative facility problem. Zellers et al[15] have indicated that this was the case in around one-third of their binocular AF fails. Finally, the youngest children in this sample, although at school, may have been too young for AF testing because their lack of familiarity with letters and words may have impacted on their ability to perform to the level of their focusing ability in the AF test. This view is shared by several who have only administered their AF testing and/or treatment in children aged 8 years and above[5,23,28].

To conclude, the repeatability of AF measurement in young children has received little research attention. In this study of the repeatability of AF measures in children aged 4-12, the results obtained indicate that AF measures are, on average, higher monocularly than binocularly and lower in the youngest children tested. Continuing testing into a second minute led to higher AF values. The results reveal marked intra-individual variability in AF measures in this paediatric sample. When considered as pass/fail, there was no evidence for false negative patterns in the data; children who initially exhibited normal AF continued to do so on repeat testing. Conversely the vast majority of children with initially-reduced AF exhibit normal performance on repeat testing. Thus a poor AF result on initial testing for one minute should be viewed with suspicion. If the result is below the level expected, the test should be continued into a second minute. If the result remains low, testing should be repeated on a subsequent occasion. The likelihood of a change from a 'fail' on initial testing to a 'pass' in minute 2, or during a subsequent test tended to be greater amongst the youngest children and, overall, poorer initial AF was found to be less likely to improve with further testing. Using established pass/fail criteria, the prevalence of persistently reduced AF in this sample is 3.6%. Reduced AF did not co-exist with abnormal NPA or reduced visual acuity.

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Competing interests: None.

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Data sharing: Data are available on request from the corresponding author: b.t.barrett@bradford.ac.uk

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Table 1. Age and visual characteristics of the study participants

	N	Gender	Age (years)	Age range (years)	R&L VA both <0.20logMAR	R LogMAR VA (mean±SD) [range]	L LogMAR VA (mean±SD) [range]
School A	76	F:50%/M:50%	7.0±1.3	(4.6 to 9.4)	69 (90.7%)	+0.07±0.08 [+0.35 to -0.10]	+0.07±0.09 [+0.33 to -0.10]
School B	60	F:32%/M:68%	9.5±2.2	(4.7 to 12.4)	48 (78.7%)	+0.04±0.15 [+0.60 to -0.25]	+0.06±0.17 [+0.80 to -0.30]
Combined	136	F:42%/M:58%	8.1±2.1	(4.6 to 12.4)	117 (85.4%)	+0.06±0.12 [+0.60 to -0.25]	+0.07±0.13 [+0.80 to -0.30]

F: female; M: male; L, left; R, right; VA, visual acuity; MAR, minimum angle of resolution

Table 2: Results of mixed-effects regression analysis performed on raw AF measures (in cpm)

AF 1st minute (cpm)	**Coefficient**	**SE**	**Z statistic**	**p value>|z|**	**95% CI**
Visit 1 v Visit 2	2.0	0.2	8.3	<0.001	1.5 to 2.4
Visit 1 v Visit 3	2.9	0.2	12.1	<0.001	2.4 to 3.3
Monoc v Binoc	-1.4	0.2	-8.5	<0.001	-1.8 to -1.1
Minute 1 v Minute 2	1.3	0.4	3.5	<0.001	0.6 to 2.0
Age 4/5 v 6/7	3.8	1.1	3.3	0.001	1.5 to 6.0
Age 4/5 v 8/9	2.0	1.2	1.7	0.090	-0.3 to 4.2
Age 4/5 v 10+	3.3	1.2	2.6	0.009	0.8 to 5.7
Minute 2 by Age 6/7	-0.5	0.5	-1.0	0.298	-1.4 to 0.4
Minute 2 by Age 8/9	-1.1	0.5	-2.3	0.023	-2.0 to -0.2
Minute 2 by Age 10+	-1.0	0.5	-2.0	0.044	-2.0 to 0.0
Constant	7.2	0.9	8.0	<0.001	5.4 to 9.0
Pooled variances (cpm)	**SD estimate**	**SE**	**95% CI**		
Variation due to tester	1.6	0.1	1.3 to 1.9		
Between-subject variation	4.0	0.3	3.4 to 4.7		
Within-subject variation	3.8	0.1	3.7 to 3.9		

The value for 'constant' (7.2cpm) is the average AF for visit 1, for minute 1, for the youngest age category (4/5 year olds) under monocular conditions. A positive coefficient value indicates, for example, that the AF at visit-2 exceeded visit-1 AF by an average of 2cpm. Negative coefficient values indicate lower AF relative to the constant value. The z statistic is used to determine whether each factor (age, visit, monocular v binocular, minute 1 v minute 2) or interaction is significant, with $p<0.05$ adopted as the criterion for statistical significance. In the final columns, the 95% confidence intervals (CI) are reported around the coefficient values; for example, the AF values at visit 1 were lower than those at visit 3 by an average of 2.9cpm, but the difference could be as low as 2.4cpm or as high as 3.3cpm.

AF: accommodation facility; cpm: cycles per minute; monoc: monocular; binoc: binocular

Table 3: Results of repeated-measures logistic regression analysis performed on 'pass' or 'fail' AF data*

AF 1st minute (cpm)	**Coefficient**	**SE**	**Z statistic**	**p value>|z|**	**95% CI**
Visit 1 v Visit 2	0.4	0.1	3.1	0.002	0.2 to 0.7
Visit 1 v Visit 3	1.2	0.1	8.1	<0.001	0.9 to 1.5
Monoc v Binoc	0.9	0.1	7.0	<0.001	0.7 to 1.2
Minute 1 v Minute 2	0.8	0.2	3.3	0.001	0.3 to 1.3
Age 4/5 v 6/7	2.3	0.5	4.4	<0.001	1.3 to 3.4
Age 4/5 v 8/9	1.5	0.5	2.8	0.005	0.5 to 2.5
Age 4/5 v 10+	1.2	0.6	2.2	0.029	0.1 to 2.4
Minute 2 by Age 6/7	-0.3	0.3	-0.9	0.392	-0.9 to 0.4
Minute 2 by Age 8/9	-0.5	0.3	-1.5	0.139	-1.1 to -0.2
Minute 2 by Age 10+	-0.7	0.3	-2.0	0.048	-1.3 to 0.0
Constant	-1.4	0.4	-3.5	0.001	-2.2 to -0.6

*The 'pass' criterion employed is ≥11cpm monocularly and ≥8cpm binocularly[15,26]. Coefficients represent probabilities that a pass will be exhibited in, for example, visit 2 compared to visit 1. In this case the coefficient is 0.4 and to work out the how the probability of a pass changes it is necessary to exponentiate this coefficient; 0.4 exponentiated is 1.49, meaning that using the aforementioned criteria, the chances of exhibiting a pass at the second visit are, relative to visit 1, increased by 1.49. AF: accommodation facility; cpm: cycles per minute; monoc: monocular; binoc: binocular. For further details see footnote to Table 2.

Table 4: Proportion of children meeting two different 'pass' criteria for AF results on repeat testing and proportion with persistently reduced AF

'Pass' criteria	**n (%) meeting 'pass' criteria in visit 1 minute 1**	**n (%) meeting 'pass' criteria by end of minute 2 in 1st visit**	**n (%) meeting 'pass' criteria following visit 2**	**n (%) meeting 'pass' criteria following visit 3**	**n (%) with persistently reduced AF**
***<u>'High Fail'</u>* ≥11cpm monocularly, ≥8cpm binocularly**	41 (36.9%)	65 (58.6%)	78 (70.3%)	93 (83.8%)	18 (16.2%) 7(38.9%) in R,L&BE 8(44.4%) in R &/or L 3(16.7%) in BE
***<u>'Low Fail'</u>* ≥6cpm monocularly, ≥3cpm binocularly**	92 (82.9%)	100 (90.1%)	107 (96.4%)	107 (96.4%)	4 (3.6%) 0(0%) in R,L&BE 3(75%) in R&/or L 1 (25%) in BE