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Title: Children's accommodation to a variety of targets – a pilot study.

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Abstract

Background Previous research indicates that a significant proportion of children underaccommodate at 1/3m. Accommodation may vary with task demand, so children may accommodate appropriately if required, for example, when reading small print. This study explores the range of accommodative responses elicited in typical children, under naturalistic conditions, to a range of targets.

Method 24 typically developing children were identified from the University of Reading Child Database. Primary school children attending UK Year 2 (age 6-7years) or Year 6 (age 10-11years) with minimum distance visual acuity of 0.200 logMAR and near visual acuity of 0.100 logMAR were recruited for participation. A remote haploscopic photorefractor was used to assess naturalistic, sustained, binocular accommodative responses to a variety of targets. At 33cm, accommodative targets included individual letters, age-appropriate text in large print equivalent to early primary school-books, small N5 equivalent print, a visual search task "Where's Wally?", a clown picture containing a range of spatial frequencies and a children's cartoon. Participants were given minimal instructions for task completion. The target presentation order was counterbalanced. The results reported in this study were obtained during a longer testing session involving different target types and fixation distances.

Results The accommodative response observed with each target varied across participants To both the clown target and single letters of a size used in school reading books the accommodative responses were 2.4±0.48D (range 0.85-2.97D) and 2.47±0.37D (range 1.48-3.09D) respectively. The accommodative response to N5 print (3.06±0.52D) was statistically better than all other targets other than the visual search and larger print tasks ($p<0.05$).

Conclusions Even to demanding N5 text, accommodation is variable between participants, but is better than that to less demanding targets. Tasks experienced by children in everyday or clinical situations will stimulate an unknown amount of accommodation for near fixation.

Introduction

Accommodative response may not always be equivalent to target demand. Child and adult accommodation studies alike frequently report some degree of accommodative lag. Where dynamic retinoscopy has been used to evaluate accommodative lag, mean lag of 0.25D – 0.75D has been reported (Jackson & Goss, 1991; Poynter et al., 1982; Tassinari, 2002). In naïve subjects age 9- 25years, Horwood et al. (2001) employed a Remote Haploscopic Photorefractor to assess accommodation under binocular conditions. The authors reported a lag of accommodation which was greatest for the nearest targets. At 4D demand a mean lag of accommodation of 1.2D was found although the subjects did not report blur and were reading aloud nonsense N5 text. Accommodative lag during sustained reading has been reported by Harb et al (2006); in a study of adult emmetropes and myopes, the authors report observed accommodative lag during sustained reading at distances of 66.6, 40 and 28.6cm, although considerable inter-subject variability is reported. Literature regarding children's accommodative responses during reading is limited and mostly concerned with refractive error development. Yeo et al (2013) report accommodative lag in children age 10.2±1.3 years during sustained reading. In their study of accommodative responses of emmetropic and myopic children to English and Chinese text at 33cm; the authors report mean accommodative lag of 1.01D±0.31 for English texts presented at 1/3m. To date there is little research documenting children's typical response to different accommodative targets such as text in comparison to pictures or cartoons.

Accommodation may be driven by blur, disparity or proximity cues. Predominantly adult research has also indicated that accommodation may also be influenced by other factors such as color, contrast, spatial frequency and higher order control.

Contrast is thought to have little practical effect on the accommodative response elicited (Denieul & Corno-Martin, 1994; Tucker et al., 1986). Color contrast has been reported as an ineffective stimulus for accommodation (Wolfe and Owens, 1981; Switkes et al., 1990).

Spatial frequency is reported to influence the accommodative response (Heath, 1956; Charman and Tucker, 1977; 1978; Owens, 1980). Ward (1987) found that higher spatial frequencies produce less accurate accommodative responses and reports that intermediate spatial frequencies are important as accommodative stimuli. Therefore, to avoid atypical accommodative responses, Ward (1987) suggests that accommodative targets should possess a wide variety of spatial frequencies, with concentration around the intermediate 5 cycles/degree.

Higher level control such as response to instruction and cognitive demand has also been shown to influence accommodative response. Ciuffreda and Hokoda (1985), using adult subjects and a sinusoidal grating target, found increased accommodation response amplitude when subjects were asked to "try very hard to keep the grating at maximum high level contrast" rather than merely "relax" when viewing the target.

Bharadwaj and Candy (2008), report that visual demand influences accommodative response. In a sample of children, aged 4.3 – 6.5yrs, participants were instructed to read letters of 20/40 size and also watch a movie, accommodation responses were recorded. It was found that under monocular conditions higher gains of accommodation were found in the letter reading task than the movie task. Thus, suggesting that children are capable of generating larger accommodative responses to visually demanding tasks.

Current literature largely focuses on adult accommodative responses and child accommodation research under naturalistic conditions is limited. As higher level control and visual demand has been shown to influence accommodative responses, children may produce more accurate accommodation if they need to. The purpose of this pilot study was to establish typical accommodation responses at 1/3m, in children, to targets of varying complexity and visual/cognitive demand. This research is part of a larger project investigating children's accommodation at various testing distances.

Materials and methods

Participants:

Children attending UK primary school Year 2 (age 6-7 years) and Year 6 (age 10-11 years) were recruited for participation from the University of Reading Child Database. Inclusion criteria was defined as minimum best corrected uniocular distance visual acuity of 0.200 logMAR and best corrected uniocular near visual acuity of 0.100 logMAR. Exclusion criteria included the presence of manifest strabismus or a history of developmental, reading or attention difficulties.

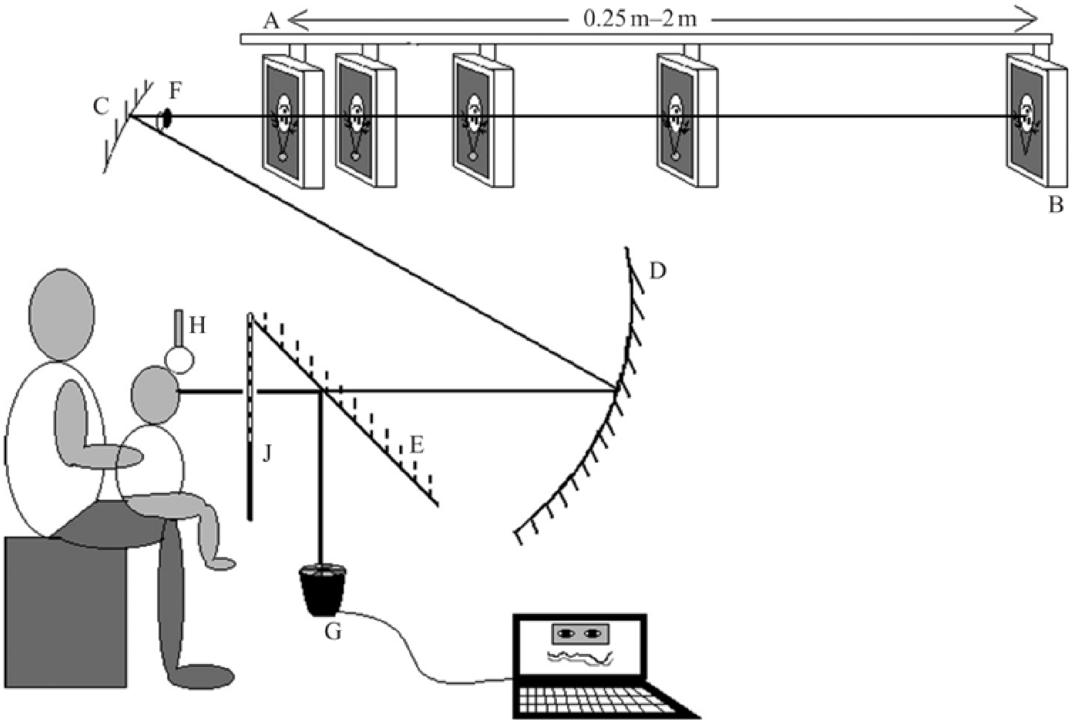
Research adhered to the Declaration of Helsinki and full ethical approval was obtained from the University of Reading Research Ethics Committee prior to the commencement of data collection. Informed written parental consent was obtained for each participant while participating children gave their assent, either written or verbal as age appropriate.

Procedure:

The results of this study were obtained during a longer testing session involving different targets and target distances. The method below details the testing procedure used at 1/3m only, using the remote halploscopic photorefractor at the University of Reading Infant Vision Laboratory. The testing procedure of the Infant Vision Laboratory has been described in detail elsewhere (Horwood and Riddell, 2008) thus, only a brief description is given here.

A remote haploscopic photorefractor was used to present seven different targets at a single viewing distance of 1/3m, producing an expected accommodative demand of 3D. Participants were instructed to rest their head against a head rest; targets were presented on a video monitor via a two way mirror system while a PlusoptiX PowerRef II photorefractor collected simultaneous binocular eye position and refraction measurements. Targets were: (1) individual letters, point size 18 (2) large text representative of early primary school text, point size 18 (3) medium text representative of upper primary text books, point size 12 (4) small text representative of that used in a clinical environment, point size 5 (5) a visual search task "Where's Wally?" (6) a clown picture containing a range of spatial frequencies (7) an animated children's cartoon providing a range of available detail and spatial frequencies. The text targets of various font sizes and the individual letters target were presented in a sans serif font style. Helvetica font was selected for use in this study and as such was used consistently across both the text and letter targets. Targets were presented in a counterbalanced order to prevent order effects. To elicit naturalistic accommodative responses to the targets, minimal instructions were given to the participants. Children were asked to simply "read the letters/story out loud" when the individual letters or text targets were presented on screen, "look for "Wally"", "watch the clown" or "watch the cartoon". Text, letters, "Where's Wally" and cartoon targets were presented to participants for at least one minute, thus providing a sustained accommodative activity for participants. The clown target was presented as part of a longer session involving various testing distances and thus, was presented at 1/3m for approximately 5 seconds per participant; which although is a shorter presentation time still allows for an adequate accommodative responseAll testing was performed by a single examiner (SL) ensuring consistency of the instruction set given to participants.

Figure 1: The remote haploscopic videorefractor.



A: motorized beam; B: target monitor; C: upper concave mirror; D: lower concave mirror; E: hot mirror; F: image of participants eye where occlusion takes place; G: PlusoptiX SO4 PowerRef II; H: headrest; J: black cloth screen that could be raised to occlude target if required.

Statistical analysis:

An Excel macro, specifically written for the Infant Vision Laboratory, allows the conversion of the refraction data obtained by the PlusoptiX PowerRef II to an accommodation response in diopters. Partially processed data is displayed in chart format, from which a vignette of 25 representative and stable data points (equivalent to one second of data) was selected for each target type. Vignettes were selected from the end of the testing session to represent accommodation following sustained activity. The resulting accommodation measurement, in diopters (D), for each target, was used for analysis. The study was a repeated measures design; analysis was performed using SPSS software for Windows, version 22. Bonferroni correction was used for post hoc multiple comparisons.

Analysis was completed both with and without the hypermetropic participant. Analysis was not affected by the inclusion of this participant and as such the below reported results are those which include this participant.

Results

24 (10 male and 14 female) typically developing children were recruited for participation in this study. Of these, 18 were current Year 2 pupils (mean age 6.39years; range 6-7years) and 6 current Year 6 pupils (mean age 10.16years; range 10-11years)

All participants met the inclusion criteria so data was collected for all 24 participants. Participants were either orthophoric on cover test or exhibited well controlled heterophoria of $<8^{\Delta}$ at both near and distance. All children demonstrated stereopsis of at least 55” of arc using the Frisby stereotest. Convergence was assessed in free space, all children demonstrated convergence within normal limits and did not report blur on convergence. 23 children did not require any refractive correction. One participant (age 10 years) did habitually use a mild hyperopic correction for closework (+1DS) and as such was assessed whilst wearing spectacles.

Accommodation to various targets

As can be seen from the mean accommodation detailed in *Table 1*, accommodative response differed across target types. Text elicited the highest mean accommodation, with the smallest text, N5 equivalent print, producing the highest mean accommodative response.

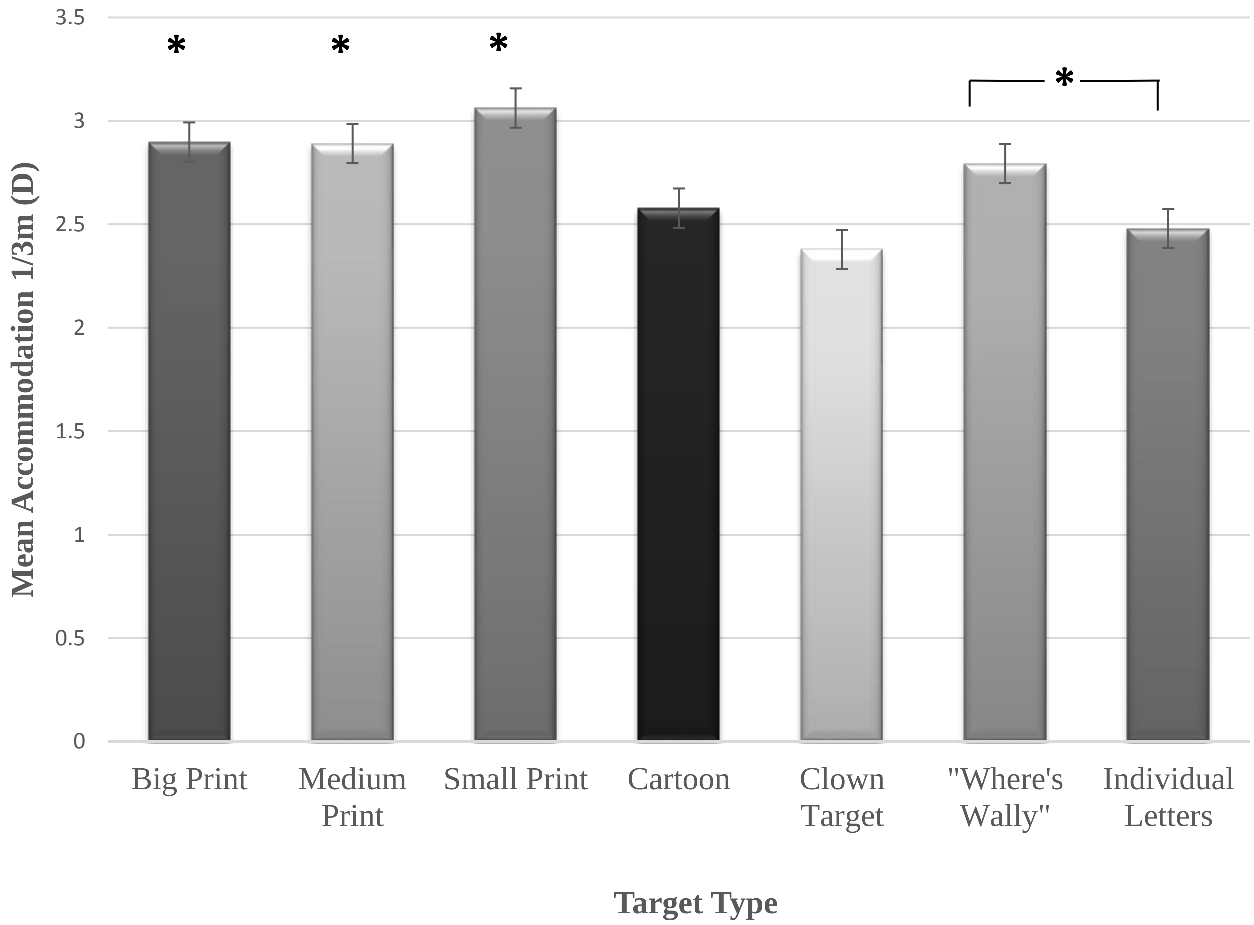
Table 1: Mean, standard deviation, minimum and maximum accommodation elicited by each target at 1/3m. Target font size given in brackets, where appropriate.

Target Type	Mean Accommodation 1/3m (D)	±Standard Deviation (D)	Minimum Accommodation (D)	Maximum Accommodation (D)
Clown	2.398	0.480	0.848	2.968
Big Print (18)	2.898	0.568	1.585	4.10
Medium Print (12)	2.907	0.448	1.669	3.646
Small Print (5)	3.062	0.524	1.752	4.347
"Where's Wally"	2.793	0.441	1.759	3.603
Cartoon	2.578	0.406	1.686	3.545
Individual Letters (18)	2.474	0.369	1.479	3.087

A one-way repeated measures analysis of variance (ANOVA) indicates that target type has a highly significant effect on the accommodative response elicited $F_{6, 138}=10.264$; $p = <0.001$.

Post hoc analysis, corrected by Bonferroni adjustment for multiple comparisons, was performed to identify the differences in accommodation elicited across target types (*Figure 2)*.

Figure 2: Mean accommodation to each target type. Bars denote ±1 standard error of the mean (SEM). * denote that the accommodative response elicited by text targets was significantly higher than that to the clown, cartoon or individual letter targets. No significant difference was found between accommodation elicited to the various text targets. Accommodation to "Where's Wally target" was significantly higher than that observed to "Individual Letters" target.



Text, regardless of size, was found to elicit a statistically significantly higher accommodation response than the clown, cartoon and individual letter targets, $p<0.05$. The difference in accommodation observed between the different sized text targets was not found to be statistically significant, $p>0.05$. The difference in accommodation elicited by the visual search task, “Where’s Wally?”, and the three text targets did not reach statistical significance, $p>0.05$.

There was no significant difference between the “Where’s Wally?”, clown and cartoon target. However, “Where’s Wally?” did produce a significantly higher accommodative response than the individual letters target, $p=0.035$.

The difference between the accommodative response to the clown, individual letters, and cartoon target was not found to be statistically significant, $p>0.05$.

Discussion

Current available literature regarding the influence of different target types on accommodation in typical children is limited. Therefore, the aim of this pilot study was to establish typical accommodation responses at 1/3m, in children, to targets of varying complexity and cognitive demand. To our knowledge no previous study has compared accommodation responses in children to such an extensive range of targets including text of various sizes as well as everyday tasks such as watching a cartoon or performing a visual search task.

The results of this study indicate that target type does have a significant influence on accommodation response in typical children. Higher level control has been found to influence the accommodative response of adult subjects resulting in increased accommodation (Ciuffreda and Hokoda, 1985). The results of this study indicate that children will accommodate as much as necessary to resolve naturalistic stimuli including pictures and cartoons, however, children produce higher and more accurate accommodative responses to the more demanding targets such as “Where’s Wally” and text targets. These findings are in agreement with that of Bharadwaj and Candy (2008), who, in a small group of 13 children, compared accommodative responses to watching a cartoon and reading 20/40 sized letters. No difference was reported in the accommodative gain observed between the letters and cartoon targets under binocular conditions. However, under monocular conditions, the authors report increased accommodative gain, i.e. less monocular lag, to the letter target, suggesting children are capable of increased accommodation to more visually demanding targets.

The above results detail accommodation under binocular conditions only. Similar to Bharadwaj and Candy (2008), we did not find a significant difference in the binocular accommodative response observed with our cartoon and letter targets. However, the difference in accommodation elicited when reading text and that observed to both the cartoon and letter targets was significant suggesting that children can produce higher accommodative response to more complex targets.

From the above results it does not appear that text font size significantly influences accommodation. The influence of font size was only investigated using text targets and not using individual letters. There may be a difference in accommodation observed with individual letters of varying sizes however we are unable to comment on this from the current data.

When presented with the individual letters target, the children were instructed to read the letters aloud as opposed to merely look at the letter, to ensure exertion of accommodation. It is interesting to note that even though the children were reading the letters aloud, the text targets used in this study still produced a higher accommodative response than the individual letters target. The individual letters and “Big Text” targets were of equivalent font size. Increased accommodation was observed with the “Big Text” target compared to the individual letters. This suggests that regardless of font size children will exert increased accommodation to more cognitively demanding tasks such as reading rather than simply identifying a single letter and at this age may still gain decoding information from individual letters as well as, or instead of, word shape.

All participants in this study were visually normal and required excellent near visual acuity for participation; yet, as can be seen in *Table 1*, even in this visually normal group there was a wide range in the accommodative responses observed to each individual target. Even to the smallest text, a wide range of accommodative responses were observed, varying between 1.752D - 4.347D. Children were not specifically asked during this study if they thought the print was blurred however, none of the children spontaneously reported blur. A single examiner performed each assessment and all children read the presented text aloud fluently. The wide range of responses observed to the various accommodative targets may have implications in the clinical environment as it suggests that not all children will produce the expected maximum accommodation, even to a visually demanding target; instead producing as much accommodation as necessary to resolve a target. However it must be noted that the children in our cohort were visually normal and did not complain of any visual symptoms and thus may be different from children attending the eye clinic complaining of blur for close work. We acknowledge that because we did not perform individual calibration of the participants in this study some of the variance in the data may be accounted for by calibration errors.

In conclusion, accommodation appears to be variable between children and may be influenced by target type. Children appear to accommodate only as much as necessary to resolve the target. More demanding tasks such as reading print or performing visual search elicits higher accommodative responses than reading letters or simply looking at a picture or cartoon. Everyday tasks and those experienced in a clinical environment may produce varying accommodative responses.

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