Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Differences in the values of anaglyphs, vectograms and cheiroscopes on participants with low, normal, and high AC/A ratio

To cite this article: Hugo Pena-Verdeal *et al* 2022 *J. Phys.: Conf. Ser.* **2407** 012033

Differences in the values of anaglyphs, vectograms and cheiroscopes on participants with low, normal, and high AC/A ratio

Hugo Pena-Verdeal, Veronica Noya-Padin, Noelia Nores-Palmas, Belen Sabucedo-Villamarin, Maria Jesus Giraldez

Departamento de Física Aplicada (Área de Optometría), Facultade de Óptica e Optometría Universidade de Santiago de Compostela, Santiago de Compostela, Spain

Corresponding author's e-mail: hugo.pena.verdeal@usc.es

Abstract. Purpose: Anaglyphs, Vectograms and Cheiroscopes are visual therapy materials based on red/green, polarized, or black/white targes that used similar but slightly different images for each eye to train fusion and vergence skills. This study aimed to analyse the differences in the results obtained on those devices on participants with low, normal, or high AC/A ratios. Material and methods: three groups of volunteer participants were recruited based on their recent clinical history among patients attending the Optometry Clinic of the centre: 15 participants with low AC/A, 15 participants with normal AC/A and 15 participants with High AC/A ratios. None of them was under any type of medication, have an ocular or systemic disease, or were performing any kind of visual training plan that could affect the study. In two sessions one week apart, following the manufacturer's instructions, the participants performed in a random order three visual therapy device-based training: one red/green Fixed Demand Anaglyph [FDA], one Variable Demand Polarized Vectogram [VDPV], and one based on the Wheatstone W [WW]. Participants were instructed to indicate the maximum value base-out (BO) where both image fusion and clarity was lost. Results between both sessions were compared with an analysis of differences. Results: There was found higher BO vergences results with the three devices regarding the second to the first session in the Low and Normal AC/A groups (Wilcoxon test, all $p \leq 0.013$), but none in the High AC/A group (Wilcoxon test, all $p \geq 0.162$). Conclusion: There is an enhancement of BO vergences in Low and normal AC/A participants but not in high AC/A participants by performing visual training with Anaglyphs, Vectograms and Cheiroscopes devices.

1. Introduction

Binocular or accommodative visual anomalies are a common group of dysfunctions that may reduce visual system efficiency [1, 2]. The relationship between accommodative/vergence anomalies and an absence of a proper diagnosis or treatment could also generate other visual problems such as amblyopia, a reduction in the binocular function or stereopsis, that may end in learning disabilities or even behavioural disorders [3-5]. Anaglyphs, Vectograms and Cheiroscopes are visual therapy materials based on red/green, polarized, or black/white targes that used similar but slightly different images for each eye to train fusion and vergence skills [6, 7]. All those tools have been usually used to practice image fusion and improvement of vergence skills [7].

Accommodation is often assumed to be primarily driven by blur meanwhile vergence is driven primarily by disparity; however, both parameters have an inherent influence on the other by a neural cross-link between them [8-11]. One of the main clinical parameters to measure this influence of one over the other is to assess the ratio of the accommodative-convergence (AC) over accommodation (A) which indicates the relationship between the amount of convergence produced by a stimulus to accommodate and the amount of accommodation which produces that convergence [12]. The measurement of the AC/A ratio is used clinically to determine the aetiology and classification of certain binocular disorders [13]. This study aimed to analyse the influence of the accommodative–vergence on the results obtained on Anaglyphs, Vectograms and Cheiroscopes on participants with low, normal, or high AC/A ratio

2. Material and Methods

2.1. Participants

For the present study, three groups of voluntary participants (a total of 45 participants; 27 female and 18 males with a mean ± SD age of 20.6 ± 2.11 from 19 to 25 years) were recruited based on their recent clinical history among patients and students attending to the Optometry Clinic of the Optometry Faculty (Universidade de Santiago de Compostela, Spain): 15 participants with low AC/A, 15 participants with normal AC/A and 15 participants with High AC/A ratio.

All of them had good ocular and general health, were free of any disease or drug that could alter the data or had performed any kind of visual training plan that could affect the study. Previous inclusion, all participants undergo a visual examination to avoid the presence of accommodative or binocular vision dysfunctions that would affect the results. Besides, before inclusion, participants completed a Convergence Insufficiency Symptom Survey (CISS) questionnaire, and their refractive correction was determined. Participants were excluded if they had a CISS ≥ 21 points, or a far or near monocular VA lower than 20/20 with their habitual refractive correction [14].

Qualified participants were scheduled for two sessions after informed consent was signed. The procedures followed the Declaration of Helsinki, and the protocol was reviewed and approved by the Ethics committee of the Universidade de Santiago de Compostela.

2.2. Study design

In two sessions two weeks apart, following the manufacturer's instructions, the participants performed in a random order three times each, the three studied visual training tools: one red/green Fixed Demand Anaglyph [FDA], one Variable Demand Polarized Vectogram [VDPV], and one based on the Wheatstone W [WW] [2, 6, 15]. Participants have not performed any kind of visual therapy program or exercises between the two sessions. Data were computed as the mean of the three measurements performed. In all cases, participants were instructed to wear their habitual refractive correction during the performance process.

2.2.1. Fixed Demand Anaglyph. FDA (Promocion Optométrica S.L., Spain) used were a single translucent card where red/green images with different prismatic demands were printed. During the procedure, the patient picks up the card at 40 cm while wearing red/green glasses [6, 7]. The patient should be able to describe the picture (for example, an elephant). The patient must concentrate on the lowest prismatic demand image and try to achieve one clear image for 10 seconds. When this goal was performed, the patient had to switch fixation to the next target and try to fuse and continue to the next one. The process was repeated three times changing fixation from one target to another until was not able to obtain a single or fuse image. On each red/green image, the trained prismatic demand value is printed (ranging from 20Δ BI to 20Δ BO). These prismatic demands are only accurate when the technique is performed at 40 cm. Participants were asked to indicate the maximum value of BO achieved as the last image that they can achieve fuse.

2.2.2. Variable Demand Polarized Vectogram. VDVP (Promocion Optométrica S.L., Spain) used were formed by a pair of translucent slides or cards with similar images but different polarizations, which were picked by patients one over the other at 40 cm while the patients wear a pair of polarized glasses [6, 7]. The patient should be able to describe the picture (for example, two circular chains). Before proceeding, the investigator should be able to establish that the patient appreciates the "depth" in the pictures over the slide. In each measurement, starting from the zero position, the participant should separate the sheets too slowly and try to keep the image single and clear. Patients should stop when they experienced a loss in the fusion as diplopia and no depth in the image. On each vectogram pair of cards, the divergence and convergence demands are printed directly next to the targets (range from 30Δ BI to 30Δ BO). These prismatic demands are only accurate when the technique is performed at 40 cm. Participants were instructed to indicate the maximum value of BO achieved as the last image that they can achieve fuse.

2.2.3. Wheatstone W. The WW (Promocion Optométrica S.L., Spain) used was a free space Wheatstone-type stereoscope formed by four panels that form the letter "W" and a holder with a scale calibrated in prismatic dioptres (range from 40Δ BI to 50Δ BO) [7]. A pair of similar but slightly different cards (for example, a clown) were inserted in both lateral panels. Participants were instructed put their nose in the central part of the structure over the central panels, and to focus their attention on two flat mirrors in the central panels, one for each eye. In each measurement, starting from the zero position, the participant should separate the two lateral panels too slowly and try to keep the image of both cards single and clear simultaneously. Participants should stop when they experienced a loss in the fusion as diplopia. Participants were instructed to indicate the maximum value of BO achieved as the last image that they can achieve fuse.

2.3. Statistical analysis

SPSS statistical software v.25.0 for Windows (SPSS Inc., USA) was used for data analysis. Significance was set at a $p \leq 0.05$ for all statistical tests. Previous to the analysis, the normal distribution of the data was checked using the Shapiro-Wilk test [16, 17]. All parameters showed a non-normal distribution (all $p \leq 0.040$) hence, non-parametric tests were used. Inter-session variation was calculated by a Wilcoxon test comparing each result obtained in both inter-week sessions on each of the studied visual training therapy tools [18, 19]. In addition, 95% limits of agreement (95% LoAs) were also calculated (Mean difference ± 1.96 x SD) [17-19].

3. Results

The values obtained with FDA, VDVP and WW were the significant statistical difference between the first and the second in Low AC/A or Normal AC/A participants (Wilcoxon, all $p \leq 0.013$, Table 1): statistically higher convergence values were obtained by using tools based on similar but slightly different images for each eye to train fusion and vergence skills one-week apart. Contrary, there was found no statistically significant difference between sessions in no one of the studied devices in High AC/A participants (Wilcoxon test, all $p \geq 0.162$).

Table 1. Descriptive statistics and Differences (Wilcoxon test) and 95% LoAs of values were obtained in each session by each of the studied visual training therapy tools. n = 15 per group. FDA: Fixed Demand Anaglyph. VDPV: Variable Demand Polarized Vectogram. WW: Wheatstone W. SD: Standard Deviation. LoAs = 95% Limits of Agreement.

Group	Device and session	Mean ± SD [Δ]	Mean difference ± SD [Δ]	p	95% LoAs [Δ]	
					Lower	Upper
Low AC/A	FDA - Session 1	5.47 ± 2.75	-6.53 ± 7.55	0.011	-21.33	8.27
	FDA - Session 2	12.00 ± 7.13				

	VDPV - Session 1	3.73 ± 4.03	-6.53 ± 7.37	0.013	-20.98	7.92
	VDPV - Session 2	10.27 ± 7.50				
	WW - Session 1	12.93 ± 7.31	-6.40 ± 6.93	0.005	-19.98	7.18
	WW - Session 2	19.33 ± 7.38				
Normal AC/A	FDA - Session 1	6.60 ± 3.33	-4.40 ± 5.25	0.011	-14.69	5.89
	FDA - Session 2	11.00 ± 7.00				
	VDPV - Session 1	4.20 ± 4.20	-5.13 ± 4.78	0.001	-14.50	4.24
	VDPV - Session 2	9.33 ± 5.81				
	WW - Session 1	15.53 ± 8.60	-5.60 ± 6.63	0.005	-18.59	7.39
	WW - Session 2	21.33 ± 6.76				
High AC/A	FDA - Session 1	7.60 ± 6.64	-0.40 ± 5.26	0.943	-10.71	9.91
	FDA - Session 2	8.00 ± 6.40				
	VDPV - Session 1	9.27 ± 6.79	-1.40 ± 6.90	0.341	-14.92	12.12
	VDPV - Session 2	10.67 ± 6.82				
	WW - Session 1	18.00 ± 8.03	-1.67 ± 4.28	0.162	-10.00	6.66
	WW - Session 2	19.67 ± 6.54				

4. Conclusion

Visual therapy material based on similar but slightly different images for each eye to train fusion and vergence skills has been often used to practice and improvement the reduced skills in accommodative and vergence disorders. In the present study, only healthy young participants non-previously diagnosed/symptomatic of binocular or accommodative problems with corrected VA of 20/20 were included to focus on the analysis itself. While vectograms and Anaglyphs are usually used by optometrists in daily visual training, few studies assessed them in detail [2, 15]. It has been established that it is as important to retain the new visual abilities as it was to train them initially, therefore, it is important to know the effectiveness of the different devices available in the market. Accommodation and convergence are a combined operation of the two systems that are different from their isolated operation, known as "Accommodative-convergence" [3-5] a decrease in the capacities in one component of this system may influence the efficiency of the other to compensate the deficiency. One parameter to describe this relationship is the "AC/A". In the present pilot study, an enhancement of BO vergences in low or normal AC/A participants was found by performing visual training with Anaglyphs, Vectograms or Cheiroscopes devices, while no difference between sessions was found in High AC/A participants.

All the methods studied here were based on similar but slightly different images for each eye to train fusion and vergence skills which were usually used by optometrists in daily visual therapy. Regarding FDA and VDPV, patients have reported more difficulty with anaglyph-type targets than polarized probably because red/green targets appear to create an obstacle to fusion, particularly for patients with moderate to severe suppression. Bogdanovich et al.[15] suggested that those difficulties may be generated by the currently available glasses which can induce significant inequalities in retinal illuminance that exacerbate suppression tendencies as well as "ghost images" and lateral chromatic aberration that could affect binocular vision. In contrast to this idea, the present study found no difference in the use of one or another method in convergence training (Table 1). There is a need for more research in the field to analyse the possible influence of visual therapy materials on patient results. In concordance with the present results, previous reports have found an improvement in the status of patients with convergence insufficiency, a condition defined as a decreased ability to converge the eyes and maintain binocular fusion while focusing on a near target [20].

On the other hand, a Wheatstone-type stereoscope used here belongs to a group of devices for viewing a stereoscopic pair of separate images, depicting left-eye and right-eye views of the same scene, as a single image with small differences [21]. This device is less common than the vectogram or anaglyph types, further investigations should be performed on its visual training capabilities.

One limitation of the present pilot study was the sample size, where only 15 participants were recruited for each group; future analysis should enlarge the sample. In addition, results were only analysed for only two sessions two weeks apart; future studies may analyse the variation in the studied parameters over a longer period. In summary, the present study has found an enhancement of convergence in low or normal AC/A participants, while no variation in high AC/A participants by performing visual training with Anaglyphs, Vectograms and Cheiroscopes devices. The present results reinforced the hypothesis that visual therapy should be personalised to the patient and the visual disorder to be treated.

References

[1] Yekta A., Khabazkhoob M., Hashemi H., Ostadimoghaddam H., Ghasemi-Moghaddam S., Heravian J., Doostdar A., Nabovati P. 2017 Binocular and Accommodative Characteristics in a Normal Population. *Strabismus* **25** (1) 5-11.

[2] Scheiman M., Wick B. *Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders*, 4rd edn: Philadelphia; 2017.

[3] Granet D.B., Gomi C.F., Ventura R., Miller-Scholte A. 2005 The relationship between convergence insufficiency and ADHD. *Strabismus* **13** (4) 163-8.

[4] Brautaset R., Wahlberg M., Abdi S., Pansell T. 2008 Accommodation insufficiency in children: are exercises better than reading glasses? *Strabismus* **16** (2) 65-9.

[5] Scheiman M., Cotter S., Kulp M.T., Mitchell G.L., Cooper J., Gallaway M., Hopkins K.B., Bartuccio M., Chung I., Convergence Insufficiency Treatment Trial Study G. 2011 Treatment of accommodative dysfunction in children: results from a randomized clinical trial. *Optom Vis Sci* **88** (11) 1343-52.

[6] Pena-Verdeal H., Calo-Santiago R., Garcia-Montero S., Vazquez-Sanchez C., Giraldez M. *Relationship between visual therapy vectograms and accommodative parameters in young healthy subjects*, Vol. 11207. SPIE; 2019.

[7] Hsieh Y.C., Liao W.L., Tsai Y.Y., Lin H.J. 2022 Efficacy of vision therapy for unilateral refractive amblyopia in children aged 7-10 years. *BMC Ophthalmol* **22** (1) 44.

[8] Maxwell J., Tong J., Schor C.M. 2012 Short-term adaptation of accommodation, accommodative vergence and disparity vergence facility. *Vision Res* **62** 93-101.

[9] Chen A.H., Abidin A.H. 2002 Vergence and accommodation system in malay primary school children. *Malays J Med Sci* **9** (1) 9-15.

[10] Abraham N.G., Srinivasan K., Thomas J. 2015 Normative data for near point of convergence, accommodation, and phoria. *Oman J Ophthalmol* **8** (1) 14-8.

[11] Jimenez R., Perez M.A., Garcia J.A., Gonzalez M.D. 2004 Statistical normal values of visual parameters that characterize binocular function in children. *Ophthalmic Physiol Opt* **24** (6) 528-42.

[12] Murray C Mres B.H., Newsham D PhD M.D.B.O. 2018 The Normal Accommodative Convergence/Accommodation (AC/A) Ratio. *J Binocul Vis Ocul Motil* **68** (4) 140-147.

[13] Jackson J.H., Arnoldi K. 2004 The Gradient AC/A Ratio: What's Really Normal? *Am Orthopt J* **54** 125-32.

[14] Rouse M., Borsting E., Mitchell G.L., Cotter S.A., Kulp M., Scheiman M., Barnhardt C., Bade A., Yamada T., Convergence Insufficiency Treatment Trial Investigator G. 2009 Validity of the convergence insufficiency symptom survey: a confirmatory study. *Optom Vis Sci* **86** (4) 357-63.

[15] Bogdanovich G., Roth N., Kohl P. 1986 Properties of anaglyphic materials that affect the testing and training of binocular vision. *J Am Optom Assoc* **57** (12) 899-903.

[16] Armstrong R.A., Davies L.N., Dunne M.C., Gilmartin B. 2011 Statistical guidelines for clinical studies of human vision. *Ophthalmic Physiol Opt* **31** (2) 123-36.
[17] Dunn G. 1992 Design and analysis of reliability studies. *Stat Methods Med Res* **1** (2) 123-57.
[18] Bland J.M., Altman D.G. 1986 Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1** (8476) 307-10.
[19] McAlinden C., Khadka J., Pesudovs K. 2011 Statistical methods for conducting agreement (comparison of clinical tests) and precision (repeatability or reproducibility) studies in optometry and ophthalmology. *Ophthalmic Physiol Opt* **31** (4) 330-8.
[20] Boon M.Y., Asper L.J., Chik P., Alagiah P., Ryan M. 2020 Treatment and compliance with virtual reality and anaglyph-based training programs for convergence insufficiency. *Clin Exp Optom* **103** (6) 870-876.
[21] Wade N.J. 2019 Ocular Equivocation: The Rivalry Between Wheatstone and Brewster. *Vision (Basel)* **3** (2)