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ABSTRACT

Purpose: Tranaglyphs and Vectograms are visual therapy material based on red/green or polarized targets respectively that used similar but slightly different images for each eye to train fusion and vergence skills. This study aimed to analyse the relationship of three accommodative parameters (the Negative Relative Accommodation [NRA], the Positive Relative Accommodation [PRA] and the Accommodative Amplitude [AA]) with the results of four different visual therapy vectograms/tranaglyphs. **Material and methods:** 45 subjects free of any accommodative or binocular problem were recruited among students attending the Optometry Clinic of the Optometry Faculty (USC). In a first session, the accommodative tests were performed according to their standard protocols. In a second session, following manufacturer's instructions, the subjects performed in a random order four different calibrated vectograms/tranaglyphs: two red/green Variable Demand Anaglyphs (one based on circles [VDA-C] and one on draws [VDA-D]), one red/green Fixed Demand Anaglyph [FDA], and one polarized with Variable Demand [VDP]. Subjects were asked to indicate the maximum value both base-out (BO) and base-in (BI), where the image fusion was lost. **Results:** NRA showed a negative correlation with the BO results of the VDP ($p = 0.040$, $r = -0.270$). PRA showed a negative correlation with the BO results of the VDA-C, the VDA-D and the VDP (all $p \leq 0.017$, $r \geq -0.323$). AA showed a positive correlation with the BI results of the VDA-D, the FDA, and the VDP (all $p \leq 0.013$, $r \geq 0.341$). **Conclusion:** Accommodation seems to have some influence on the visual therapy training with vectograms and tranaglyphs.

Keywords: Visual therapy, Optometry, Accommodative Amplitude, Negative Relative Accommodation, Positive Relative Accommodation, Variable Demand Anaglyphs, Fixed Demand Anaglyph, Polarized Vectograms

1. INTRODUCTION

Accommodative and vergence anomalies are a common group of visual dysfunction that reduces the efficiency of the visual system [1, 2]. The relationship between accommodative/vergence anomalies and learning disabilities and even behavioural disorders has been established, especially in children [3, 4]. Moreover, an absence of a proper diagnosis may generate decompositions which can have consequences such as amblyopia or loss of binocular function and stereopsis. Consequently to a diagnosis, a proper treatment of those anomalies is an important issue in the field of optometry and visual sciences [4, 5]. Tranaglyphs and vectograms are visual therapy material based on red/green or inverse polarized printed targets respectively that utilize specific glasses to present similar but slightly different images to each eye. They are one of the most used tools to practice image fusion and improvement of convergence and divergence skills.

Usually, it was assumed that accommodation is driven primarily by blur while vergence is driven primarily by disparity but both have an influence on the other by the neural cross-links between the two systems (vergence–accommodation and accommodative–vergence respectively) [6-9]. While the dynamics of accommodation following visual therapy have been measured objectively the associated accommodative–vergence has not. This study aimed to analyse the relationship of three accommodative parameters with the results of four different visual therapy vectograms.

2. MATERIAL AND METHODS

2.1 Participants and procedure

For the present study a total of 45 subjects (27 female and 18 male), with a mean ± SD age of 20.6 ± 2.11 (from 19 to 25) years were recruited among patients and students attending to the Optometry Clinic of the Optometry Faculty

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(Universidade de Santiago de Compostela, Spain). All of them had good ocular and general health, were no previously diagnosed or have complained/symptoms of accommodative or binocular problems and were free of any disease or drug that could alter the data. Besides, before inclusion, subjects completed a Convergence Insufficiency Symptom Survey (CISS) questionnaire and their refractive correction was determined. Subjects were excluded if they had a CISS $\geq$ 21 points or far or near monocular VA lower than 20/20 [10]. Qualified subjects 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 Accommodative parameters

In the first scheduled session, the accommodative parameters were evaluated in each subject. Tests were performed according to their standard protocols three times always in the same order: Negative relative accommodation (NRA), positive relative accommodation (PRA) and accommodative amplitude (AA) [1, 2, 6, 8]. Data were computed as the mean of the three measurements performed.

NRA and PRA were measured at 40 cm while focusing a VA of 25/20 by adding plus and minus lenses (0.25 dioptre [D] steps) binocularly in the phoropter until first sustained blur. AA was measured monocular using Donder's method in which the accommodative target (one line above best near vision corrected VA) was brought closer to the eye until the first sustained blur. Patients were instructed to wear their habitual refractive correction during all accommodative parameters measuring process.

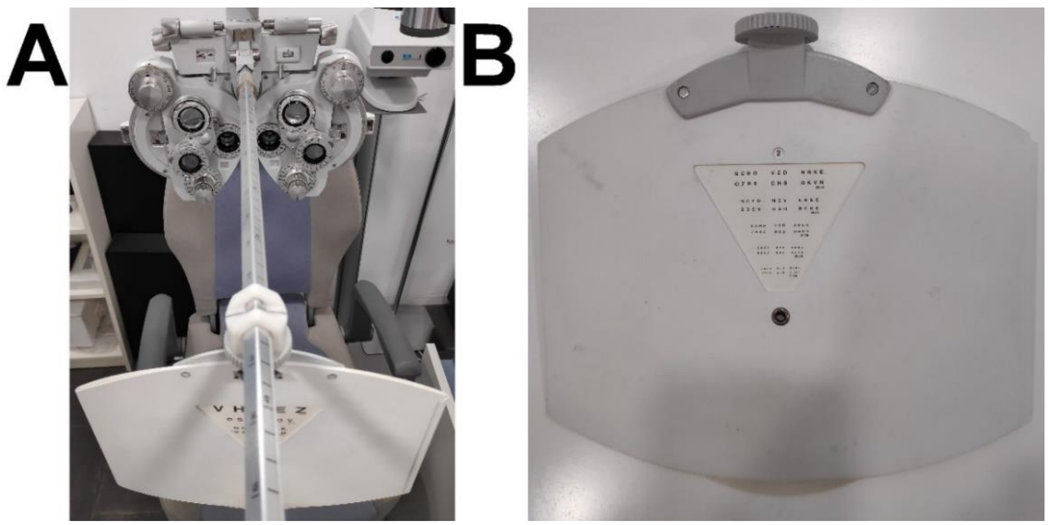

Figure 1. A) Phoropter and near test at 40 cm, B) Near test used in the study Fox the NRA, PRA and AA calculation

2.3 Vectograms and Tranaglyphs

In the second scheduled session, following manufacturer's instructions, the subjects performed three times each, in a random order, four different calibrated vectograms/tranagyphs: two red/green Variable Demand Anaglyphs (one based on circles [VDA-C] and one on draws [VDA-D], Figure 2A y 2B), one red/green Fixed Demand Anaglyph [FDA] (Figure 2C), and one polarized with Variable Demand [VDP] (Figure 2D) [2, 11]. Data were computed as the mean of the three measurements performed. Similar to the evaluation of the accommodative parameters, in all cases patients were instructed to wear their habitual refractive correction during all the performance process.

Variable demand vectograms and tranaglyphs were formed by a pair of translucent slides or cards with similar images but different colours or polarizations, which were picks by patients one over the other at 40 cm. During the procedure, the patient wears the red/green glasses for the anaglyphs and the specifically polarized glasses for the polarized one. The patient should be able to describe the picture (for example, two large circles surrounded by four small circles). Before proceeding, the investigator should be able to establish that the patient appreciates the "depth" in the circles. In each of the three measurements, starting on zero position, the patient had to separate the sheets too slowly and try to keep the circles 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. These prismatic demands are only accurate when the technique is performed at 40 cm. Subjects were asked to indicate the maximum value of convergence and divergence, both base-out (BO) and base-in (BI) vergence respectively, where the image fusion was lost.

Fixed demand anaglyph was formed by a single translucent card where red/green images with different prismatic demand were printed. During the procedure, the patient picks the card at 40 cm while wears the red/green glasses. The patient should be able to describe the picture (for example, a fox). 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. The process was repeated three times changing fixation from one target to another until was no able to obtain a single or fuse image. On each red/green image, the trained prismatic demand value is printed. These prismatic demands are only accurate when the technique is performed at 40 cm. Subjects were asked to indicate the maximum value (as the last image that they can achieve fuse), both BO and BI.

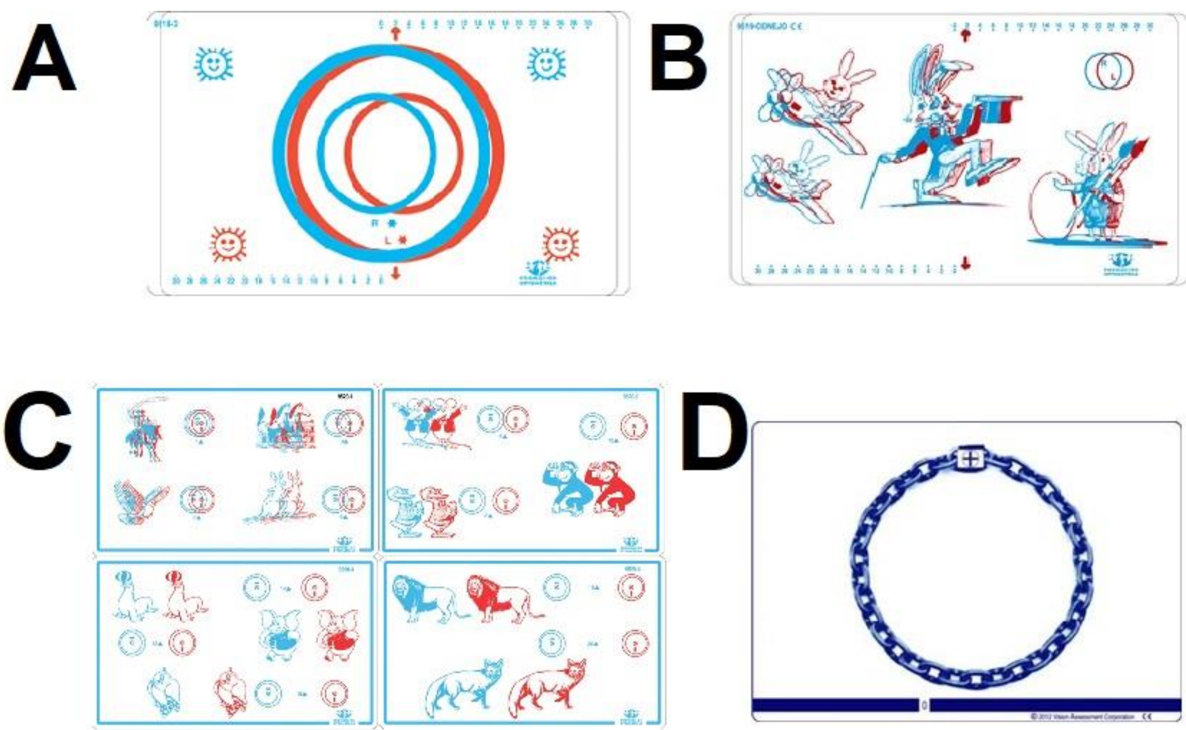

Figure 2. Vectograms and tranaglyphs used in the study. A) Variable Demand Anaglyphs based on circles (Promoción Optotomérica, Spain), B) Variable Demand Anaglyphs based on draws (Promoción Optotomérica, Spain), C) A set of Fixed Demand Anaglyph (Promoción Optotomérica, Spain), D) Polarized Variable Demand Vectogram (Bernell Corporation, USA).

2.4 Statistical analysis

SPSS statistical software v.19.0 for Windows (SPSS Inc., Chicago, IL) was used for data analysis. Significance was set at a $p \leq 0.05$ for all statistical tests. Previous to analysis, the normal distribution of the data was checked using the Kolmogorov-Smirnov test [12]. All parameters showed a non-normal distribution (all $p \leq 0.040$). For the analyses, the AA used was the mean AA between the values obtained in each eye. Differences between pairs of results of vectograms and all types of tranaglyphs were analysed by a Wilcoxon test. Relationships between the accommodative parameters and vectograms prismatic demand results were assessed through Spearman ρ for non-parametric data. Correlations between variables was described as weak (0.2 – 0.4), moderate (0.4 – 0.6), good (0.61 – 0.8), or strong (0.8 – 1.0)[13].

3. RESULTS

Table 1 shows the descriptive statistics of the accommodative test evaluated. Table 2 shows the descriptive statistics of the prismatic demand values obtained in each of the vectograms performed. In all cases, while non-parametric descriptive statistics were showed (median, inter-quartile range (IQR)), mean and standard deviation (SD), as well as maximum and minimum, are also provided for comparisons with other studies. CISS questionnaires showed a mean ± SD age of 8.98 ± 3.35 (from 0 to 16) points.

Table 1. Descriptive statistics of the accommodative parameters obtained in the first session. n = 45 subjects. SD = Standard Deviation. IQR = Interquartile Range. NRA = Negative Relative Accommodation. PRA = Positive Relative Accommodation. AA = Accommodative Amplitude.

Accommodative parameter	Mean ± SD	Median	IQR	Minimum	Maximum
NRA (D)	2.34 ± 0.47	2.25	2.00 - 2.50	1.25	3.25
PRA (D)	3.52 ± 1.03	3.50	3.00 - 4.00	1.00	5.25
Mean AA (D)	9.88 ± 1.93	10.00	8.62 - 11.38	7.25	13.75

Table 2. Descriptive statistics of the prismatic demand results obtained on each visual training vectograms and tranaglyphs used in the study. n = 45 subjects. SD = Standard Deviation. IQR = Interquartile Range. BO = Base-out. BI = Base-in.

	Base	Mean ± SD	Median	IQR	Minimum	Maximum
Variable Demand Anaglyph [Circles] (Δ)	BO	17.33 ± 10.84	16.00	8.00 - 30.00	2.00	30.00
	BI	8.37 ± 5.33	10.00	4.00 - 12.00	1.00	22.00
Variable Demand Anaglyph [Draws] (Δ)	BO	15.40 ± 11.01	12.00	6.00 - 28.00	1.00	30.00
	BI	7.77 ± 4.54	6.00	4.00 - 10.00	2.00	17.00
Fixed Demand Anaglyph (Δ)	BO	6.95 ± 4.32	6.00	4.00 -10.00	0.00	20.00
	BI	5.16 ± 3.20	4.00	3.00 - 6.00	0.00	14.00
Polarized Variable Demand (Δ)	BO	6.58 ± 5.97	4.00	2.00 - 11.00	0.00	17.00
	BI	3.37 ± 2.48	3.00	2.00 - 5.00	0.00	8.00

Table 3 shows the differences between the prismatic demand results obtained in vectograms and tranaglyphs analysed by pairs. To avoid type I errors arising from multiple comparisons in the analysis, statistical significance ($p \leq 0.05$) was divided by the number of comparisons performed to give a $p \leq 0.008$ [12]. Only three comparisons between methods showed no differences between them: two on BO comparison results, VDA-C vs. VDA-D (Wilcoxon test: p = 0.155) and FDA vs. VDP (Wilcoxon test: p = 0.711); and one in the BI comparison results, VDA-C vs. VDA-D (Wilcoxon test: p = 0.255). All the other comparisons showed a statistical difference, both BO (Wilcoxon test: all $p \leq 0.001$) and BI (Wilcoxon test: all $p \leq 0.001$).

Table 3. Differences (Wilcoxon test) and 95% LoAs between prismatic demand results obtained on each visual training vectogram and tranaglyphs used in the study. n = 45 subjects. SD = Standard Deviation. LoAs = Limits of agreement. BO = Base-out. BI = Base-in.

Base	Pair	Mean Difference	SD	p	95% LoAs	
					Lower	Upper
BO	VDA-C (BO) [Δ] - VDA-D (BO) [Δ]	1.93	8.73	0.155	-15.18	19.04
	VDA-C (BO) [Δ] - FDA (BO) [Δ]	10.37	9.91	< 0.001	-9.05	29.79
	VDA-C (BO) [Δ]] - VDP (BO) [Δ]	10.74	7.96	< 0.001	-4.86	26.34
	VDA-D (BO) [Δ] - FDA (BO) [Δ]	8.44	10.51	< 0.001	-12.16	29.04
	VDA-D (BO) [Δ] - VDP (BO) [Δ]	8.81	9.49	< 0.001	-9.79	27.41
	FDA (BO) [Δ] - VDP (BO) [Δ]	0.37	6.53	0.711	-12.43	13.17
BI	VDA-C (BI) [Δ] - VDA-D (BI) [Δ]	0.61	3.44	0.255	-6.13	7.35
	VDA-C (BI) [Δ] - FDA (BI) [Δ]	3.21	5.48	< 0.001	-7.53	13.95
	VDA-C (BI) [Δ] - VDP (BI) [Δ]	5.00	4.96	< 0.001	-4.72	14.72
	VDA-D (BI) [Δ] - FDA (BI) [Δ]	2.60	4.30	< 0.001	-5.83	11.03
	VDA-D (BI) [Δ] - VDP (BI) [Δ]	4.40	3.71	< 0.001	-2.87	11.67
	FDA (BI) [Δ] - VDP (BI) [Δ]	1.79	3.38	0.001	-4.83	8.41

Table 4 shows the correlation results between the accommodative parameters and the results obtained in the visual training vectograms used in the present study. The NRA parameter showed only a significant negative correlation with the BO results on the VDP (Spearman correlation test: p = 0.040, r = - 0.270) (Table 4). The PRA parameter showed a significant negative correlation with the BO results of the VDA-C (Spearman correlation test: p = 0.005, r = - 0.384), the VDA-D (Spearman correlation test: p = 0.001, r = - 0.464), and the VDP (Spearman correlation test: p = 0.017, r = - 0.323) (Table 4). The AA parameter showed a significant positive correlation with the BI results of the VDA-D (Spearman correlation test: p = 0.013, r = 0.341), the FDA (Spearman correlation test: p < 0.001, r = 0.507), and the VDP (Spearman correlation test: p = 0.005, r = 0.386) (Table 4).

Table 4. Spearman Correlation between the accommodative parameters and the results obtained in the visual training vectogram. n = 45 subjects. NRA = Negative Relative Accommodation. PRA = Positive Relative Accommodation. AA = Accommodative Amplitude. BO = Base-out. BI = Base-in.

	Variable Demand Anaglyph [Circles] (Δ)		**Variable Demand Anaglyph [Draws] (Δ)**		**Fixed Demand Anaglyph (Δ)**		**Polarized Variable Demand (Δ)**	
	BO	**BI**	**BO**	**BI**	**BO**	**BI**	**BO**	**BI**
NRA	r = - 0.021 p = 0.447	r = - 0.085 p = 0.294	r = - 0.134 p = 0.196	r = - 0.082 p = 0.300	r = - 0.079 p = 0.308	r = - 0131 p = 0.201	r = - 0.270* p = 0.040	r = 0.026 p = 0.434
PRA	r = - 0.384* p = 0.005	r = 0.005 p = 0.487	r = - 0.464* p = 0.001	r = 0.046 p = 0.385	r = - 0.144 p = 0.179	r = - 0.125 p = 0.213	r = - 0.323* p = 0.017	r = 0.104 p = 0.253
AA	r = - 0.157 p = 0.157	r = 0.028 p = 0.429	r = 0.105 p = 0.252	r = 0.341* p = 0.013	r = 0.246 p = 0.056	r = 0.507* p = 0.000	r = 0.022 p = 0.444	r = 0.386* p = 0.005

4. CONCLUSION

In the present pilot study, it was found a correlation between accommodation parameters and the results of different visual therapy variable and fixed prismatic demand vectograms and tranaglyphs. The present results were the initial findings of ongoing research on visual therapy material characteristics analysis. To focus the analysis only in healthy young subjects, inclusion criteria of non-previously diagnosed or symptomatic binocular or accommodative problems and a corrected VA of 20/20 was set. However, it is important to note that there seem to be some patients with initial or non-diagnosed problems in the studied sample (Table 1).

The present results showed that, in general, there is a statistical difference in the prismatic demand results obtained between the different types of vectograms and tranaglyphs (Table 3). The only major exception was the variable demand anaglyphs based on circles or draws, which seems to be interchangeable both for BO and BI visual therapy training (Table 3). While vectograms and tranaglyphs are usually used by optometrists in the daily visual therapy, few studies assessed in detail their real performance [2, 11]. Clinically, the only important difference between vectograms types is the principle used, polarized or anaglyphic (Figure 2). However, patients seem to experience more difficulty with anaglyph-type targets than polarized. The use of red/ green targets appears to create an obstacle to fusion, particularly for patients with moderate to severe suppression. Bogdanovich et al. [11] 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. Contrary, in the present study, variable anaglyphic vectogram have shown greater prismatic demand results than the polarized ones (Table 2). There is a need for more research on the field to analyse the possible influence of visual therapy materials in the patient results.

In concordance with the literature, PRA showed a statistical negative correlation with the convergence results (BO) in the three variable vectograms/tranaglyphs (the VDP, the VDA-C, and the VDA-D) (Table 4): lower or higher convergence capacities are inversed correlated to the positive relative accommodation capacities such as one should compensate the other. Contrary to this theory, NRA also showed a statistically negative correlation in the VDP with the BO results. It has been previously established that accommodation and convergence are a combined operation of the two systems that are different from their isolated operation, known as "Accommodative convergence" [6-9]; a decrease in the capacities in one of the components of this systems may have an influence on the efficiency of the other in order to compensate the deficiency. On the other hand, the AA parameter showed a significant positive correlation with the BI results of the VDA-D, the FDA (Spearman correlation test: p < 0.001, r = 0.507), and the VDP (Spearman correlation test: p = 0.005, r = 0.386) (Table 4): higher or lower accommodation amplitude capacities are direct correlate with higher or lower divergence capacities during vectograms performance. One limitation of the study is that the refractive error was determined without cycloplegia; this could underestimate the hyperopic correction of some patients and could affect the results of accommodative parameters (the maximum value of NRA was +3.25 D). However, we wanted to perform the study with their habitual correction that subjects can tolerate, and sometimes the cycloplegic correction is not the case, We also have to point out that NRA/PRA tests are subjective and this result could be motivated by the misinterpretation of the patient Another important limitation of the present results was the possible presence of some patients with non-diagnosed or uncorrected visual problems. Future analysis should enlarge the sample and analysed the here reported relationship on different binocular or accommodative diagnosed problems.

In summary, the present study has found that accommodative parameters seem to have some influence in visual therapy training with vectograms.

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REFERENCES

[1] A. Yekta, M. Khabazkhoob, H. Hashemi *et al.*, "Binocular and Accommodative Characteristics in a Normal Population," Strabismus, 25(1), 5-11 (2017).
[2] M. Scheiman, and B. Wick, [Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders], Philadelphia(2017).
[3] D. B. Granet, C. F. Gomi, R. Ventura *et al.*, "The relationship between convergence insufficiency and ADHD," Strabismus, 13(4), 163-8 (2005).
[4] R. Brautaset, M. Wahlberg, S. Abdi *et al.*, "Accommodation insufficiency in children: are exercises better than reading glasses?," Strabismus, 16(2), 65-9 (2008).
[5] M. Scheiman, S. Cotter, M. T. Kulp *et al.*, "Treatment of accommodative dysfunction in children: results from a randomized clinical trial," Optom Vis Sci, 88(11), 1343-52 (2011).
[6] J. Maxwell, J. Tong, and C. M. Schor, "Short-term adaptation of accommodation, accommodative vergence and disparity vergence facility," Vision Res, 62, 93-101 (2012).
[7] A. H. Chen, and A. H. Abidin, "Vergence and accommodation system in malay primary school children," Malays J Med Sci, 9(1), 9-15 (2002).
[8] N. G. Abraham, K. Srinivasan, and J. Thomas, "Normative data for near point of convergence, accommodation, and phoria," Oman J Ophthalmol, 8(1), 14-8 (2015).
[9] R. Jimenez, M. A. Perez, J. A. Garcia *et al.*, "Statistical normal values of visual parameters that characterize binocular function in children," Ophthalmic Physiol Opt, 24(6), 528-42 (2004).
[10] M. Rouse, E. Borsting, G. L. Mitchell *et al.*, "Validity of the convergence insufficiency symptom survey: a confirmatory study," Optom Vis Sci, 86(4), 357-63 (2009).
[11] G. Bogdanovich, N. Roth, and P. Kohl, "Properties of anaglyphic materials that affect the testing and training of binocular vision," J Am Optom Assoc, 57(12), 899-903 (1986).
[12] R. A. Armstrong, L. N. Davies, M. C. Dunne *et al.*, "Statistical guidelines for clinical studies of human vision," Ophthalmic Physiol Opt, 31(2), 123-36 (2011).
[13] G. Dunn, "Design and analysis of reliability studies," Stat Methods Med Res, 1(2), 123-57 (1992).