ORIGINAL ARTICLE

The Effectiveness of Dichoptic Therapy in Treating Convergence Insufficiency: A Pilot Randomized Control Trial

Norsyahirah Mohamad Azmi[1], Nur Amani Izzati Mat Ghani[1], Noor Wafirah Shafee [1,2*]

[1]Department of Optometry & Visual Science, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, 25200 Kuantan, Pahang, Malaysia
[2] Integrated Omics Research Group (IORG), Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Pahang, Malaysia

ABSTRACT

Background: Convergence insufficiency (CI) is a common non-strabismic binocular vision disorder that causes eyestrain, headaches, diplopia and difficulty concentrating during near tasks. It is especially prevalent among young adults who perform prolonged near work, such as university students. Vision therapy remains the mainstay for CI management. While traditional office-based and home-based therapies are effective, newer technology-driven methods such as dichoptic mobile therapy have recently emerged. However, evidence supporting their efficacy remains limited. **Aim:** To evaluate the effectiveness of dichoptic mobile therapy in improving binocular vision parameters in individuals with convergence insufficiency compared to a placebo control. **Methodology:** Fourteen volunteers aged 18–25 years with symptomatic CI were recruited and randomly assigned to an experimental group (using red–green anaglyph filters) or a placebo group (without filters). Both groups completed 20 minutes of therapy. Pre- and post-therapy assessments included visual acuity, near point of convergence (NPC), negative and positive fusional vergence (NFV, PFV), amplitude of accommodation (AA), accommodative facility and vergence facility. Data were analysed using SPSS version 20. **Result:** The experimental group demonstrated significant improvement in near PFV and vergence facility following therapy. No significant changes were observed in NPC, NFV, AA or accommodative facility. Between-group differences were not statistically significant. **Conclusion:** Dichoptic mobile therapy using red–green filters shows a potential for improving near PFV and vergence facility in individuals with convergence insufficiency. Further studies with larger sample sizes and extended intervention periods are recommended to validate these findings.

Keywords:
Convergence insufficiency; eyestrain; dichoptic mobile therapy; vergence facility; red-green filter

INTRODUCTION

Convergence insufficiency (CI) is one of the most common binocular vision disorders, making near tasks such as reading and computer work challenging. CI occurs when the eyes are unable to converge effectively for near vision, resulting in poor binocular vision coordination at close work. During reading, one or both eyes may drift outward, leading to symptoms such as headache, eyestrain (asthenopia), double vision (diplopia), blurred vision and difficulty concentrating or maintaining reading comprehension. CI is more prevalent among younger individuals, particularly university students, due to their increased exposure to near work, which involves prolonged screen time and reading. Reported prevalence rates of convergence insufficiency (CI) vary widely, from 1.75% to 33% (Cooper, 2012). A prevalence of CI among individuals aged 18–35 years was 27.5% (Vaishali et al., 2019), which is consistent with the 29.6% prevalence found in those aged 15–28 years (Ovenseri-Ogbomo & Eguegu, 2016).

With the rise of the Fourth Industrial Revolution (4IR), near visual demands among young individuals have increased significantly. This shift, which was accelerated by the COVID-19 pandemic and the widespread adoption of online learning , has led to prolonged use of digital devices and near tasks. Such sustained visual effort is a known risk factor for CI, as it strains the vergence and accommodative systems, leading to eyestrain, poor eye coordination and reduced concentration, which ultimately affect quality of life and academic performance (Scheiman et al., 2005). Vision therapy remains a primary intervention for managing symptoms of CI. While conventional methods have long been used, newer approaches such as dichoptic

**Corresponding author*
E-mail address: wafirah@iium.edu.my

Journal homepage: https://journals.iium.edu.my/ijahs/index.php/IJAHS
EISSN NO 2600-8491

mobile therapy, offer a modern, technology-driven alternative.

In convergence insufficiency (CI), deficits in motor fusion and suppression limit binocular efficiency, contributing to poor vergence coordination and reduced ability to sustain convergence during near tasks (Menigite & Taglietti, 2017). Dichoptic therapy presents different visual stimuli to each eye, promoting simultaneous binocular viewing, reducing suppression, and strengthening sensory fusion (Xiao et al., 2022). By targeting these deficits, dichoptic training encourages binocular integration, enhances fusion performance, stimulates fusional reserves, and facilitates vergence adaptation, potentially addressing both the sensory and motor components underlying CI.

While conventional vision therapy has shown good outcomes in managing CI, limited research has explored the short-term effects of dichoptic mobile therapy specifically on binocular motor function. Dichoptic training may offer advantages in enhancing sensory fusion and vergence facility through simultaneous binocular stimulation using interactive digital platforms. However, its immediate clinical impact on core binocular vision parameters remains unclear. This pilot randomized controlled trial (RCT) aims to evaluate the short-term effectiveness of dichoptic mobile therapy in improving key binocular vision parameters in individuals with convergence insufficiency.

MATERIALS AND METHODS

Study design and population

This study adhered to CONSORT guidelines for pilot RCT. It was designed as a pilot RCT to evaluate the short-term effectiveness of dichoptic mobile therapy.

It also complied with the principles of the Declaration of Helsinki. Ethical approval was obtained from the International Islamic University Malaysia Research Ethics Committee (IREC) (IREC 2024-KAHS/DOVS6). G*Power version 3.1.9.3 (Heinrich Heine University Dusseldorf, Germany), a statistical power analysis tool, was used to calculate the required sample size for this study.

Fourteen volunteers aged 18–25 years with symptomatic convergence insufficiency (CI) were recruited through convenience sampling. The minimum sample size was calculated using the formula for comparing two means (Equation 1):

$$n=\frac{2\sigma^2(Z_{1-\alpha/2}+Z_{1-\beta})^2}{\Delta^2} \quad (1)$$

where σ represents the standard deviation, $Z_{1-}\alpha/2$ is the standard normal deviate for a two-tailed test at a 95% confidence level (1.96), $Z_{1-}\beta$ corresponds to a statistical power of 80% (0.84) and Δ is the minimum detectable difference between groups. Based on previous studies of convergence insufficiency therapy, an effect size (Δ) of 4 prism diopters and a standard deviation (σ) of 3.5 were assumed.

The calculation yielded a minimum of six participants per group. To compensate for potential dropouts, a 15% adjustment was applied, giving a total of 14 participants (7 per group). This sample size was deemed adequate for a pilot randomized controlled trial evaluating the short-term effect of dichoptic mobile therapy on binocular vision parameters in CI.

This pilot RCT was designed to observe and compare the short-term effects of dichoptic mobile therapy on binocular vision function in individuals diagnosed with CI. Participants were followed over a defined intervention period, allowing for the assessment of within-group changes and between-group differences, thereby strengthening the validity of the findings. Randomisation was performed using a computer-generated random number sequence, with simple random allocation into experimental and placebo groups.

Inclusion criteria for this study were comprised students from the International Islamic University Malaysia Kuantan aged 18 to 25 years, who were visual acuity of 6/6 at distance for each eye and generally healthy, not taking any medications or drugs, had never undergone refractive surgery and had score ≥16 on the Convergence Insufficiency Symptom Survey (CISS). Participants who had amblyopia, constant strabismus, nystagmus, a history of ocular trauma, vertical heterophoria greater than 1ΔD and learning disability were excluded from this study.

Data collection

Before participation, all 14 eligible participants were fully briefed about the study objectives and procedures, and written informed consent was obtained. Background information and eligibility were verified using a screening questionnaire based on inclusion and exclusion criteria. Eligible participants were then randomly assigned into two groups: Group 1 (experimental), who performed the GamE-blyopia application with red–green anaglyph filters, and Group 2 (placebo), who performed the same application without the filters.
Standardized procedures were applied for all binocular vision assessments at both baseline and post-intervention

(after 20 minutes of therapy). Near point of convergence (NPC) was assessed using a RAF ruler at 40 cm under normal room illumination. Positive and negative fusional vergence (PFV/NFV) were measured using prism bars at 40 cm with binocular viewing. Vergence facility was tested using 12Δ BO/3Δ BI prism flippers at 40 cm, while monocular and binocular accommodative facility (MAF and BAF) were evaluated using ±2.00 D lens flippers. Visual acuity (VA) was measured using a standard Snellen chart, and monocular amplitude of accommodation (AA) was assessed using the push-up method. All parameters were reassessed after the therapy session to enable comparison between pre- and post-intervention outcomes in participants with symptomatic convergence insufficiency. A summary of the flow of participants through the study procedures is presented in Figure 1.

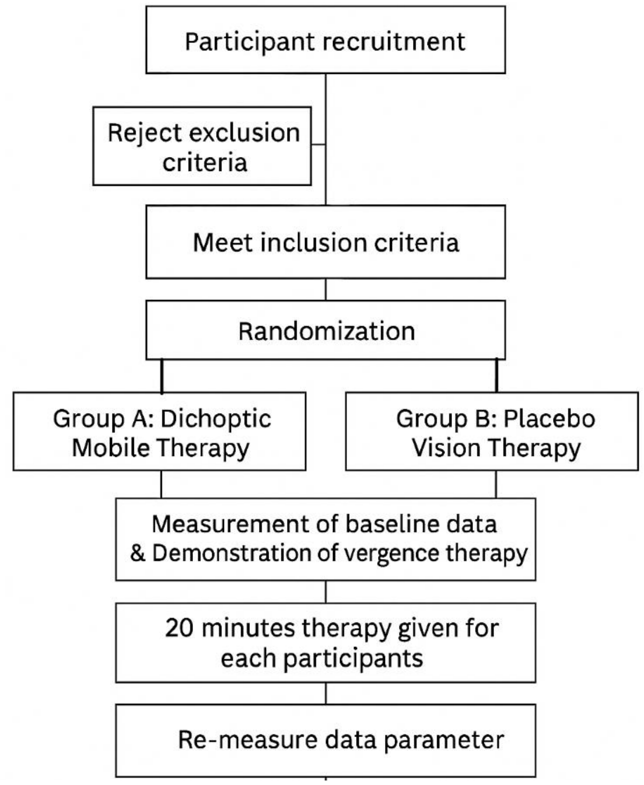

Figure 1: CONSORT flow diagram of participant recruitment, randomization, allocation, and analysis for the pilot RCT.

Assessments followed standardized order: (1) VA, (2) NPC, (3) PFV/NFV, (4) AA, (5) accommodative facility, (6) vergence facility. Testing was conducted in controlled lighting with 5-minute rest if needed. Although a 20-minute intervention does not represent the duration of conventional vision therapy, previous studies have demonstrated that short-term dichoptic and vergence-based training can produce measurable changes in binocular function and are appropriate for assessing immediate responsiveness in pilot trials (Jenewein et al., 2023).

Statistical Analysis

Data were coded and entered into Microsoft Excel, then exported to Statistical Package for the Social Sciences (SPSS) version 20 for analysis and cleaning. Means and standard deviations were calculated for the quantitative variables. Data normality was checked using the Kolmogorov-Smirnov test. Due to small sample size and non-normal distribution (Kolmogorov-Smirnov test), non-parametric tests were chosen (Wilcoxon signed-rank for within-group, Mann-Whitney U for between-group analyses). Data were screened for entry errors and outliers using boxplot and z-score (±3). No data points were excluded as no extreme outliers were detected.

RESULTS

The experimental group (with red-green filters) consisted of 8 participants (1 male, 7 females), with a mean age of 21.5 ± 1.5 years. The placebo group (without red-green filters) consisted of 6 participants (1 male, 5 females), also with a mean age of 21.5 ± 1.5 years.

Within-group comparisons demonstrated that participants in the experimental group showed significant improvements in near PFV, $p = 0.046$, and VF, $p = 0.026$, after undergoing dichoptic mobile therapy (Table 1). The increase in PFV suggests a strengthening of the convergence system and improved ability to sustain binocular fusion during near tasks. Similarly, the improvement in VF indicates enhanced flexibility and responsiveness of the vergence mechanism, reflecting better adaptation to varying vergence demands.

Other visual parameters including NPC, NFV, AA, BAF and MAF, did not show statistically significant changes following therapy. The absence of change in accommodative and convergence break/recovery measures suggests that a single 20-minute session of dichoptic training may primarily influence vergence dynamics rather than accommodative or tonic components.

In contrast, participants in the placebo group (without red-green filters) showed a significant improvement in BAF ($p = 0.039$) after therapy, while all other parameters remained statistically unchanged (Table 1). The observed increase in BAF within this group may reflect a short-term learning or practice effect from repeated testing, which can enhance accommodative response speed even in the absence of dichoptic stimulation.

Table 1: The effect of dichoptic mobile therapy on participants with symptomatic CI.

Variables	Group	N	Pre Median	Post Median	P-Value
NPC break	With R/G	8	6.00	5.50	0.157
	Without R/G	6	6.00	6.50	0.180
NPC recovery	With R/G	8	7.00	6.50	0.683
	Without R/G	6	6.50	7.00	0.180
PFV @ N	With R/G	8	17.00	20.00	0.046*
	Without R/G	6	20.50	18.00	0.500
NFV @ N	With R/G	8	18.00	18.00	0.527
	Without R/G	6	16.00	16.00	0.157
AA RE	With R/G	8	11.50	10.00	0.414
	Without R/G	6	10.00	9.50	0.564
AA LE	With R/G	8	12.00	11.50	1.000
	Without R/G	6	10.50	10.00	0.705
BAF	With R/G	8	10.00	9.50	0.257
	Without R/G	6	10.00	12.50	0.039*
MAF RE	With R/G	8	10.00	10.50	0.059
	Without R/G	6	8.50	8.00	0.461
MAF LE	With R/G	8	10.00	10.50	0.176
	Without R/G	6	7.50	9.50	0.157
VF	With R/G	8	12.50	15.00	0.026*
	Without R/G	6	9.00	10.00	0.129

Notes: R/G = Red-Green filters; NPC = Near Point of Convergence; PFV = Positive Fusional Vergence; NFV = Negative Fusional Vergence; AA = Amplitude of Accommodation; RE = Right Eye; LE = Left Eye; BAF = Binocular Accommodative Facility; MAF = Monocular Accommodative Facility; VF = Vergence Facility
*Significant level at p<0.05

Between-group comparisons using the Mann-Whitney U test revealed no statistically significant differences between the experimental and placebo groups for any of the visual parameters ($p > 0.05$ for all; Table 2). The result shows that, although the experimental group demonstrated within-group improvements in PFV and VF, these gains were not significantly greater than those observed in the placebo group.

Table 2: Comparison of visual parameters in participants with symptomatic CI after 20 minutes of dichoptic mobile therapy with and without red-green filters.

Variables	Group	N	U	P-value
NPC break	With R/G	8	16.50	0.300
	Without R/G	6		
NPC recovery	With R/G	8	17.50	0.370
	Without R/G	6		
PFV @ N	With R/G	8	11.50	0.104
	Without R/G	6		
NFV @ N	With R/G	8	20.50	0.647
	Without R/G	6		
AA RE	With R/G	8	24.00	1.000
	Without R/G	6		
AA LE	With R/G	8	19.00	0.491
	Without R/G	6		
BAF	With R/G	8	11.50	0.091
	Without R/G	6		
MAF RE	With R/G	8	23.00	0.890
	Without R/G	6		
MAF LE	With R/G	8	22.00	0.788
	Without R/G	6		
VF	With R/G	8	12.00	0.111
	Without R/G	6		

Notes: R/G = Red-Green filters; NPC = Near Point of Convergence; PFV = Positive Fusional Vergence; NFV = Negative Fusional Vergence; AA = Amplitude of Accommodation; RE = Right Eye; LE = Left Eye; BAF = Binocular Accommodative Facility; MAF = Monocular Accommodative Facility; VF = Vergence Facility; U = Mann–Whitney U Test statistic
*Significant level at p<0.05

DISCUSSION

Recent advancements in vision therapy have embraced modern technology to more effectively address binocular vision disorders. Dichoptic therapy is one such innovation: it presents different visual stimuli to each eye simultaneously (often via red-green filters), promoting binocular cooperation and reducing suppression. In the present study, dichoptic mobile therapy using red–green anaglyph filters produced significant within-group improvements in PFV and vergence facility, suggesting strengthened sensory fusion and enhanced flexibility of the motor vergence system. These findings are consistent with Li et al. (2013), who demonstrated that dichoptic training promotes binocular integration by reducing interocular suppression and enhancing cortical plasticity, even over a relatively short training duration. Similarly, Levi et al. (2015) highlighted that dichoptic stimulation can facilitate sensory fusion and improve binocular function through simultaneous stimulation of both eyes, which may explain the measurable changes in PFV observed in this pilot trial. Our findings also align with dichoptic-based interventions in amblyopia and binocular dysfunction, where improvements in sensory fusion and vergence control were reported following dichoptic training (Li et al., 2013; Levi et al., 2015).

However, unlike studies involving longer-duration therapy or multiple training sessions that demonstrated broader improvements across NPC, accommodative facility, and symptom scores (Cooper, 2012; CITT-ART Investigator Group, 2019), this study demonstrated measurable change predominantly in PFV and VF, which are known to respond more rapidly to vergence stimulation. The improvement in VF indicates increased vergence adaptability and response speed, consistent with Jenewein et al. (2023), who reported early improvements in vergence dynamics during the initial phase of therapy. The absence of significant changes in accommodative parameters and NPC in our study may be attributed to the short intervention duration, as these parameters may require cumulative training effects or repeated sessions to demonstrate meaningful change. While no between-group differences were found, the within-group improvements in PFV and VF support the potential of dichoptic mobile therapy as a short-term stimulus for enhancing sensory fusion and motor vergence function in individuals with CI.

For example, the multicenter Convergence Insufficiency Treatment Trial-Attention & Reading Trial (CITT-ART) found a mean increase in PFV of approximately 14.4Δ ($P < 0.001$) after office-based vergence/accommodative therapy in children with symptomatic CI (CITT-ART Investigator Group, 2019). Similarly, a time-course study reported that the fastest rate of improvement in NPC and PFV occurred within the first 4 weeks of therapy, with PFV improving by about 3.2Δ/week (Jenewein et al., 2023). Moreover, review evidence indicates that computer-based or dichoptic therapy in adults with CI can lead to increased PFV (e.g., mean increase of 17.7Δ in a small sample) and reduced symptoms (Cooper, 2012).

Thus, the significant improvements seen in PFV and VF in our pilot RCT suggest that the dichoptic mobile therapy may activate and enhance the vergence system's ability to adapt rapidly to fusion demands. Because VF assesses the speed and flexibility of vergence responses (cycles per minute, cpm), an increase in VF denotes improved motor fusion responsiveness, which is critical for sustained near tasks. By promoting binocular cooperation through red-green filter dichoptic stimuli, the therapy likely strengthens fusional vergence reserves and supports sensory fusion mechanisms.

To extract direct practical implications: in CI, the difficulty often lies in sustaining convergence under near demands and resisting exophoria drift. Improvements in PFV enlarge the fusional reserve capacity and enhanced VF indicates better dynamic responsiveness. Hence, our findings align well with theoretical frameworks that reinforce the role of targeted binocular stimuli in treating convergence dysfunctions.

Interestingly, the placebo group (without red-green filters) also demonstrated a significant improvement in binocular accommodative facility (BAF). This improvement may reflect a practice or learning effect, rather than a genuine change in binocular fusion or vergence mechanisms. In other words, repeated exposure to the testing procedure, increased familiarity with the tasks and greater visual engagement during the therapy session may have enhanced the speed and accuracy of the accommodative response even in the absence of dichoptic stimulation. Several studies support this phenomenon, one reliability study found significant increases in accommodative facility (both monocular and binocular) simply due to repeated testing over three consecutive weeks, suggesting a learning effect on the facility measure. Another study exploring accommodative facility training reported that facility can improve via direct training in myopes and emmetropes over short time intervals (McKenzie et al., 1987). Given these findings, the improvement in BAF in the placebo group likely represents task-familiarity rather than an effect of the dichoptic therapy, and this should be considered when interpreting the outcome (Allen et al., 2010).

Despite these within-group improvements, no statistically significant differences emerged between the experimental and placebo groups across all parameters. Importantly, this absence of between-group difference is not necessarily due to insufficient sample size (our sample met the pre-calculated minimum), but is more likely explained by the short duration of the therapy session (20 minutes). It is plausible that a longer or repeated therapy regimen would be required to produce measurable inter-group differences in binocular function.

Overall, the findings suggest that dichoptic mobile therapy using red-green filters can generate measurable short-term improvements in vergence performance (particularly PFV and VF) among individuals with CI. However, the results also indicate that sustained and broader improvements across other binocular and accommodative parameters likely require longer intervention periods or repeated sessions. Moreover, the interactive and gamified nature of the mobile platform may enhance patient engagement and adherence compared to conventional therapies, a promising feature for clinical implementation.

CONCLUSION

Recent innovations such as dichoptic mobile therapy, delivered through the GamE-blyopia application application using red-green filters, show promise in enhancing near PFV and VF among individuals with CI. This approach may serve as an effective and accessible adjunctive therapy to conventional vision training by improving binocular motor function while increasing patient motivation and compliance through its interactive design. However, as this was a short-term pilot study with a small sample size, further research with larger cohorts, extended therapy durations and long-term follow-up is needed to validate its therapeutic potential and sustained clinical efficacy.

LIMITATIONS

Although the sample size in this study was small, it met the minimum requirement based on prior sample size calculations to achieve adequate statistical power for detecting meaningful differences. Therefore, the sample size is considered sufficient for a pilot randomized controlled trial. However, as a preliminary investigation, the limited number of participants may restrict the generalizability of the findings to a broader population. In addition, the uniform duration and frequency of therapy sessions may have influenced the measured outcomes. Future studies should include larger and more diverse participant groups, extended follow-up periods and comparisons with alternative treatment modalities such as conventional orthoptic exercises or virtual reality-based vision therapy to better evaluate the long-term efficacy and clinical applicability of dichoptic mobile therapy.

ACKNOWLEDGEMENT

The author extends sincere appreciation to the Department of Optometry and Visual Sciences, International Islamic University Malaysia (IIUM), Kuantan Campus, for their support and to all participants for their involvement in this study.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the author(s) used ChatGPT (OpenAI) to assist in drafting and refining the text. The author(s) subsequently reviewed, revised, and approved all content, and accept full responsibility for the final manuscript.

REFERENCES

1. Allen, P. M., Charman, W. N., & Radhakrishnan, H. (2010). Changes in dynamics of accommodation after accommodative facility training in myopes and emmetropes. *Vision Research*, *50*(10), 947–955. https://doi.org/10.1016/j.visres.2010.03.007

2. CITT-ART Investigator Group. (2019). Treatment of symptomatic convergence insufficiency in children enrolled in the convergence insufficiency treatment trial-attention & reading trial: A randomized Clinical trial. *Optometry and Vision Science*, *96*(11), 825–835. https://doi.org/10.1097/OPX.0000000000001443

3. Cooper, J. (2012). Convergence insufficiency-a major review. In *Article in Optometry-Journal of the American Optometric Association*. https://www.researchgate.net/publication/233899973

4. Jenewein, E. C., Cotter, S., Roberts, T., Kulp, M., Mitchell, G. L., Jones-Jordan, L. A., Chen, A. M., Hopkins, K., Huang, K., Amster, D., Fecho, G., Tyler, J., Meiyeppen, S., Scheiman, M., Cooper, J., Schulman, E., Hamian, K., Iacono, D., Larson, S., & Varghese, R. (2023). Vergence/accommodative therapy for symptomatic convergence insufficiency in children: Time course of improvements in convergence function. *Ophthalmic and Physiological Optics*, *43*(1), 105–115. https://doi.org/10.1111/opo.13062

5. Levi, D. M., Knill, D. C., & Bavelier, D. (2015). Stereopsis

and amblyopia: A mini-review. In *Vision Research* (Vol. 114, pp. 17–30). Elsevier Ltd. https://doi.org/10.1016/j.visres.2015.01.002

6. Li, J., Thompson, B., Deng, D., Chan, L. Y. L., Yu, M., & Hess, R. F. (2013). Dichoptic training enables the adult amblyopic brain to learn. In *Current Biology* (Vol. 23, Issue 8). Cell Press. https://doi.org/10.1016/j.cub.2013.01.059

7. McKenzie, K. M., Kerr, S. R., Rouse, M. W., & DeLand, P. N. (1987). Study of accommodative facility testing reliability. *Am J Optom Physiol Opt.*, *64*(3), 186.

8. Menigite, N. C., & Taglietti, M. (2017). Visual symptoms and convergence insufficiency in university teachers. Revista Brasileira de Oftalmologia, 76(5), 242–246. https://doi.org/10.5935/0034-7280.20170050

9. Ovenseri-Ogbomo, G. O., & Eguegu, O. P. (2016). Resultados vergenciales y disfunciones de las vergencias horizontales entre los estudiantes universitarios de primer año de Benin City, Nigeria. *Journal of Optometry*, *9*(4), 258–263. https://doi.org/10.1016/j.optom.2016.01.004

10. Scheiman, M., Lynn Mitchell, ; G, Cotter, S., & Cooper, J. (2005). A Randomized Clinical Trial of Treatments for Convergence Insufficiency in Children. Arch Opthalmol., 123, 14–24.

11. Vaishali, R., Jha, K., & Srikanth, K. (2019). Prevalence of convergence insufficiency between 18 and 35 years and its relation to body mass index. *TNOA Journal of Ophthalmic Science and Research*, *57*(1), 27. https://doi.org/10.4103/tjosr.tjosr_11_19

12. Xiao, S., Angjeli, E., Wu, H. C., Gaier, E. D., Gomez, S., Travers, D. A., Binenbaum, G., Langer, R., Hunter, D. G., & Repka, M. X. (2022). Randomized controlled trial of a dichoptic digital therapeutic for amblyopia. Ophthalmology, 129(1), 77–85. https://doi.org/10.1016/j.ophtha.2021.09.001