Review Article

The Evolution of Vision Therapy: From Conventional Orthoptic Techniques to Modern Digital and Artificial Intelligence-Driven Rehabilitation Systems

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Abstract

Aim: To critically review the evolution of vision therapy (VT) from traditional orthoptic methods to contemporary digital, virtual reality (VR), and artificial intelligence (AI)-assisted systems, with a focus on VTS4, HoloLens, and Cognihab platforms.

Methods: A structured narrative review was conducted using peer-reviewed literature indexed in PubMed, Scopus, and Web of Science (2000–2026). The study surveys original research papers on over 30 - 40 verified platforms, evaluating software-based advantages and clinical success rates.

Results: Traditional office-based therapy remains effective for convergence insufficiency (73–75% success). The Visual Training System 4 (VTS4), particularly with HoloLens AR integration, provides true 3D color vergence training with independent eye tracking. AI-driven VR suites like Cognihab have reported an 85% success rate in visual acuity improvement within 12 weeks. AI and machine learning (ML) integration has catalyzed a massive expansion in home-based programs, which now demonstrate adherence rates as high as 94% compared to 40 to 57% for traditional patching.

Conclusion: Vision therapy has transitioned into an integrated neuro-rehabilitation specialty. The integration of ML-based adaptive algorithms has shifted the focus toward scalable, home-based models that offer objective monitoring and enhanced patient engagement while maintaining clinical standards.

Keywords: Vision therapy, Conventional Orthoptic Techniques, Artificial Intelligence

Introduction

Vision therapy, also known as behavioral optometry, began as a branch of optometry started by Arthur Marten Skeffington to treat visual disorders using methods outside of traditional optometric or orthoptic teaching. It is an evidence-based clinical program designed to enhance visual functions, including binocular coordination, tracking, and information processing, by leveraging cortical neuroplasticity.[1] Historically, the field was characterized by "orthoptics," focusing on mechanical muscle training using analog tools. However, the last two decades have seen a fundamental shift toward digital therapeutics (DTx).[2] The emergence of sophisticated Vision Therapy Software (VTS) represents a paradigm shift toward data-driven, interactive, and AI-assisted rehabilitation that brings therapy beyond clinical walls into the patient's home.

Historical Context and Technology Evolution

Vision therapy has matured through four distinct stages, moving from manual mechanical tools to closed-loop neural stimulation.

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How to cite this article: Ganesh S, Nagendran I, Roy L, Parthasarathy A. The Evolution of Vision Therapy: From Conventional Orthoptic Techniques to Modern Digital and Artificial Intelligence-Driven Rehabilitation Systems. UP Journal of Ophthalmology. 2026;14(2): 61-65.
Received: 22-05-2026, **Accepted:** 16-06-2026, **Published:** 01-08-2026

UP JOURNAL OF OPHTHALMOLOGY
An Official Journal of Uttar Pradesh State Ophthalmological Society, UPSOS (Northern Ophthalmological Society, NOS)
p-ISSN: 2250-1916 | DOI: 10.56692/upjo.2026140204

Table 1: Chronological evolution of in-office and home-based paradigms

Era	*Clinical focus*	*In-office technology*	*Home-based technology*	*Reference basis*
Traditional (Pre-2000)	Muscle strengthening	Brock string, Synoptophore, Prism bars	Pencil push-ups, Hart charts	Mechanical muscle focus
Digital automation (2000-2015)	Monocular stimulation	Computerized Orthoptics (COI), early VTS4	Home Therapy System (HTS)	Automation of analog tasks
Dichoptic period (2016-2022)	Anti-suppression	Liquid Crystal shutter goggles	Luminopia, CureSight, iPad games	Targeting cortical suppression
AI & immersive (2023-2026)	Integrated Neuroplasticity	VTS4 HoloLens, VR headsets	Cognihab, AI-driven mobile apps	Real-time adaptive rehab

Table 2: Comparative advantages and evolution of care delivery

Parameter	*Traditional in-office VT*	*Modern home-based software (AI/ML)*
Accessibility	Clinic dependent; high travel burden	Remote, on-demand training from home
Adherence	Often low (40-57% in patching)	High (up to 94%) due to gamification
Monitoring	Subjective, intermittent observation	Objective, real-time remote analytics
Personalization	Therapist-driven adjustments	AI-driven adaptive difficulty/content
Engagement	Repetitive, sometimes tedious drills	Immersive 3D environments and VR games
Cost	Higher per-session facility fees	Lower long-term costs; eliminated travel

Table 3: Technical performance of ai gaze tracking and prediction models

Architecture	*Model example*	*Key innovation*	*Accuracy (Angular error)*
Residual CNN	RAGE-net	Calibrationless webcam tracking	3.96 circ - 4.08 circ
Vision transformer	Gaze Prophet	LSTM-based temporal encoding	3.83 circ (VR optimized)
Multi-stream CNN	MSMI-Net	Parallel spatial/channel attention	High Stability in Eye-Face features
CNN-GRU hybrid	Research Tool	Spatiotemporal feature fusion	Improved blink/sequence detection

Table 4: Analysis of constraints in modern vision rehabilitation

Category	*Primary challenge*	*Clinical implication*
Physiological	Vergence-Accommodation Conflict (VAC)	Causes asthenopia and «cybersickness» in VR
Technical	Algorithmic Bias	Models may underperform in diverse age groups or ethnicities
Operational	Supervision Paradox	Professional guidance is still required to ensure proper technique
Economic	Hardware Costs	High-end VR headsets/HoloLens can be cost-prohibitive
Regulatory	Standardization Gap	Lack of universal clinical guidelines for digital dosage

Survey of Professional Research Platforms

Visual Training System 4 (VTS4) and HoloLens AR

The VTS4 is a clinically validated platform that assesses and trains the three grades of binocular vision: simultaneous macular perception (SMP), fusion, and stereopsis.

Mechanism

It uses liquid crystal shutter goggles synced with screen refresh rates to provide dichoptic viewing, allowing for precise vergence rehabilitation and accommodative facility enhancement.

HoloLens AR Integration

Utilizing Microsoft HoloLens technology, the VTS4HOLO system presents over 100 targets in true 3D color. It incorporates independent eye tracking to determine the position of both eyes at all times, facilitating precise vergence and version training within an augmented environment.

Clinical Outcomes

Research indicates that VTS4 adjuvant therapy improves the effective rate of visual recovery in refractive amblyopia to 86.49%, compared to 66.18% in control groups.

Cognihab: Machine Learning-Based VR Suite

Cognihab is a health-tech platform utilizing AI-driven gaming modules for amblyopia and strabismus recovery.

Signal Strength Modification

The software splits the virtual world into two images, automatically decreasing signal strength for the dominant eye and increasing it for the amblyopic eye to force binocular cortical integration.

Adaptive ML Algorithms

Machine learning models analyze patient performance in real time to adapt task difficulty and contrast balance, ensuring exercises remain in the "Zone of Proximal Development".

Therapeutic Efficacy

Preliminary outcomes for gamified modules indicate that 85% of compliant patients achieve a minimum improvement of one line in visual acuity within 12 weeks of treatment.

Advantages of Home-Based Digital Vision Therapy

The integration of AI and ML has catalyzed a significant increase in home-based vision therapy programs, offering several clinical and operational advantages over traditional models.

Impact of AI/ML Integration

Following the integration of intelligent algorithms, clinicians can now track patient progress remotely via cloud-based dashboards, allowing for real-time therapy adjustments. This has reduced the dependence on frequent clinic visits while improving the precision of treatment protocols through biometric feedback.

Technical Architecture of Modern AI Systems

Modern systems have transitioned from geometric eye models to appearance-based deep learning, enabling high-precision gaze tracking without dedicated hardware.

Limitations and Challenges

Despite technological maturation, several barriers persist in the transition to fully autonomous digital care.

Conclusion

Vision therapy has evolved from qualitative, therapist-led drills to a quantitative medical science powered by AI and immersive technology. Professional platforms like VTS4 and Cognihab demonstrate that integrated machine learning can significantly improve adherence and clinical outcomes. The future lies in a hybrid model where clinician expertise is augmented by adaptive software, enabling scalable and personalized care that overcomes geographical and physiological barriers.

References

1. Wang, B., & Kuwera, E. (2022). Vision Therapy: A Primer and Caution for Pediatricians. *Children (Basel, Switzerland)*, *9*(12), 1873. https://doi.org/10.3390/children9121873
2. Abdal, M. O., Bhombal, F., Nankani, G. J., Nankani, S. G., Lad, S., Dholam, A., Kumari, R., Mahajan, J., & Piñero, D. P. (2022). Evaluation of the Efficacy of a New Dichoptic Digital Platform to Treat the Anisometropic and Isometropic Amblyopia. *Brain sciences*, *12*(7), 815. https://doi.org/10.3390/brainsci12070815
3. Alvarez, T. L., Scheiman, M., Hajebrahimi, F., Noble, M., Gohel, S., Baro, R., Bachman, J. A., Master, C. L., Goodman, A., & CONCUSS Investigator Group (2026). CONCUSS randomised clinical trial of vergence/accommodative therapy for concussion-related symptomatic convergence insufficiency. *British journal of sports medicine*, *60*(5), 340–354. https://doi.org/10.1136/bjsports-2025-109807
4. Alvarez, T. L., Vicci, V. R., Alkan, Y., Kim, E. H., Gohel, S., Barrett, A. M., Chiaravalloti, N., & Biswal, B. B. (2010). Vision therapy in adults with convergence insufficiency: clinical and functional magnetic resonance imaging measures. *Optometry and vision science : official publication of the American Academy of Optometry*, *87*(12), E985–E1002. https://doi.org/10.1097/OPX.0b013e3181fef1aa
5. Alvarez TL, Scheiman M, Hajebrahimi F CONCUSS Investigator Group, *et al* CONCUSS randomised clinical trial of vergence/accommodative therapy for concussion-related symptomatic convergence insufficiency *British Journal of Sports Medicine* 2026;60:340-354.
6. Artiaga, J. C. M., Guevarra, M. C. B., Sosuan, G. M. N., Agnihotri, A. P., Nagel, I. D., & Kalaw, F. G. P. (2025). Large language models in ophthalmology: a scoping review on their utility for clinicians, researchers, patients, and educators. *Eye (London, England)*, *39*(15), 2752–2761. https://doi.org/10.1038/s41433-025-03935-7
7. Dang, R. M., Jalbert, I., Hui, A., & Kang, P. (2025). Measuring Treatment Adherence in Myopia Control: Current Practices and Future Directions. *Ophthalmology science*, *6*(1), 100949. https://doi.org/10.1016/j.xops.2025.100949
8. Birch, E. E., Jost, R. M., De La Cruz, A., Kelly, K. R., Beauchamp, C. L., Dao, L., Stager, D., Jr, & Leffler, J. N. (2019). Binocular amblyopia treatment with contrast-rebalanced movies. *Journal of AAPOS : the official publication of the American Association for Pediatric Ophthalmology and Strabismus*, *23*(3), 160.e1–160.e5. https://doi.org/10.1016/j.jaapos.2019.02.007
9. Birch, E. E., Li, S. L., Jost, R. M., Morale, S. E., De La Cruz, A., Stager, D., Jr, Dao, L., & Stager, D. R., Sr (2015). Binocular iPad treatment for amblyopia in preschool children. *Journal of AAPOS : the official publication of the American Association for Pediatric Ophthalmology and Strabismus*, *19*(1), 6–11. https://doi.org/10.1016/j.jaapos.2014.09.009
10. Shao, W., Niu, Y., Wang, S., Mao, J., Xu, H., Wang, J., Zhang, C., & Guo, L. (2023). Effects of virtual reality on the treatment of amblyopia in children: A systematic review and meta-analysis. *Journal of pediatric nursing*, *72*, 106–112. https://doi.org/10.1016/j.pedn.2023.07.014
11. Edwards, T., & Harding, J. E. (2021). Clinical Aspects of Neonatal Hypoglycemia: A Mini Review. *Frontiers in pediatrics*, *8*, 562251. https://doi.org/10.3389/fped.2020.562251
12. Zhou, C., Li, X., Luo, X., Song, S., Wang, L., Huang, J., Zhang, X., Liu, D., Chai, Y., & Zhou, J. (2026). Research hotspots and trends of amblyopia treatment from 2015 to 2025: a bibliometric analysis. *Frontiers in neuroscience*, *19*, 1720376. https://doi.org/10.3389/fnins.2025.1720376
13. Gao, T. Y., Guo, C. X., Babu, R. J., Black, J. M., Bobier, W. R., Chakraborty, A., Dai, S., Hess, R. F., Jenkins, M., Jiang, Y., Kearns, L. S., Kowal, L., Lam, C. S. Y., Pang, P. C. K., Parag, V., Pieri, R., Raveendren, R. N., South, J., Staffieri, S. E., Wadham, A., … BRAVO Study Team (2018). Effectiveness of a Binocular Video Game vs Placebo Video Game for Improving Visual Functions in Older Children, Teenagers, and Adults With Amblyopia: A Randomized Clinical Trial.

JAMA ophthalmology, *136*(2), 172–181. https://doi.org/10.1001/jamaophthalmol.2017.6090

14. Nagendran, I., Roy, L., Ravikumar, P., Gireesh, P., Kaur, K., & Gurnani, B. (2025). The Evolution of Vision Therapy Software and Its Impact on Vision Care - A Comprehensive Major Review. *Romanian journal of ophthalmology*, *69*(4), 495–511. https://doi.org/10.22336/rjo.2025.78
15. Hess, R. F., Mansouri, B., & Thompson, B. (2010). A new binocular approach to the treatment of amblyopia in adults well beyond the critical period of visual development. *Restorative neurology and neuroscience*, *28*(6), 793–802. https://doi.org/10.3233/RNN-2010-0550
16. Holmes, J. M., Manh, V. M., Lazar, E. L., Beck, R. W., Birch, E. E., Kraker, R. T., Crouch, E. R., Erzurum, S. A., Khuddus, N., Summers, A. I., Wallace, D. K., & Pediatric Eye Disease Investigator Group (2016). Effect of a Binocular iPad Game vs Part-time Patching in Children Aged 5 to 12 Years With Amblyopia: A Randomized Clinical Trial. *JAMA ophthalmology*, *134*(12), 1391–1400. https://doi.org/10.1001/jamaophthalmol.2016.4262
17. Wenner, Yaroslava & Schneider, Johann & Drisser, Timo & Yang, Yu & Demeter, Thilo & Fronius, Maria & Lorenz, Birgit & Kohnen, Thomas & Mueller, Michael & Triesch, Jochen. (2025). Virtual reality-based Harms tangent screen test for strabismus measurement. Graefe's Archive for Clinical and Experimental Ophthalmology. 263. 1435-1442. 10.1007/s00417-024-06724-2.
18. Nughays, R. O., Almazroy, E. A., Elyas, S. K., Alamoudi, A., Batais, W. T., Bogari, A. M., Alnabihi, A., Alkharboush, D. H., & Almarzouki, H. (2025). Efficacy of Dichoptic Treatment vs Eye Patching in Pediatric Patients with Amblyopia: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Clinical ophthalmology (Auckland, N.Z.)*, *19*, 1999–2009. https://doi.org/10.2147/OPTH.S513329
19. Knox, P. J., Simmers, A. J., Gray, L. S., & Cleary, M. (2012). An exploratory study: prolonged periods of binocular stimulation can provide an effective treatment for childhood amblyopia. *Investigative ophthalmology & visual science*, *53*(2), 817–824. https://doi.org/10.1167/iovs.11-8219
20. 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 : official publication of the American Academy of Optometry*, *96*(11), 825–835. https://doi.org/10.1097/OPX.0000000000001443
21. Eduard Kuric, Peter Demcak, Jozef Majzel, Giang Nguyen,Democratizing eye-tracking? Appearance-based gaze estimation with improved attention branch,Engineering Applications of Artificial Intelligence,Volume 149,2025,110494,ISSN 0952-1976, https://doi.org/10.1016/j.engappai.2025.110494.
22. Li, S. L., Jost, R. M., Morale, S. E., De La Cruz, A., Dao, L., Stager, D., Jr, & Birch, E. E. (2015). Binocular iPad treatment of amblyopia for lasting improvement of visual acuity. *JAMA ophthalmology*, *133*(4), 479–480. https://doi.org/10.1001/jamaophthalmol.2014.5515
23. Liang, Y. G., Fan, L., Teixeira-Pinto, A., Liew, G., & White, A. J. R. (2026). A systematic review of AI for predicting glaucoma progression: challenges and recommendations towards clinical implementation. *NPJ digital medicine*, *9*(1), 140. https://doi.org/10.1038/s41746-025-02321-7
24. Luminopia, Inc. (2025). FDA K243819 Clearance for Amblyopia (4-12 years). April 2025.
25. Manh, V. M., Holmes, J. M., Lazar, E. L., Kraker, R. T., Wallace, D. K., Kulp, M. T., Galvin, J. A., Shah, B. K., Davis, P. L., & Pediatric Eye Disease Investigator Group (2018). A Randomized Trial of a Binocular iPad Game Versus Part-Time Patching in Children Aged 13 to 16 Years With Amblyopia. *American journal of ophthalmology*, *186*, 104–115. https://doi.org/10.1016/j.ajo.2017.11.017
26. Manny, R. E., Holmes, J. M., Kraker, R. T., Li, Z., Waters, A. L., Kelly, K. R., Kong, L., Crouch, E. R., Lorenzana, I. J., Alkharashi, M. S., Galvin, J. A., Rice, M. L., Melia, B. M., Cotter, S. A., & Pediatric Eye Disease Investigator Group (2022). A Randomized Trial of Binocular Dig Rush Game Treatment for Amblyopia in Children Aged 4 to 6 Years. *Optometry and vision science : official publication of the American Academy of Optometry*, *99*(3), 213–227. https://doi.org/10.1097/OPX.0000000000001867
27. NeuroEars Inc. (2025). NeuroEars-Anna™ Nystagmograph. FDA K243709. Class II Nystagmograph.
28. Oculogica, Inc. (2025). EyeBOX EBX-4.1. FDA K242116. Traumatic Brain Injury Eye Movement Assessment Aid.
29. Pineles, S. L., Aakalu, V. K., Hutchinson, A. K., Galvin, J. A., Heidary, G., Binenbaum, G., VanderVeen, D. K., & Lambert, S. R. (2020). Binocular Treatment of Amblyopia: A Report by the American Academy of Ophthalmology. *Ophthalmology*, *127*(2), 261–272. https://doi.org/10.1016/j.ophtha.2019.08.024
30. Ramanathan, Vanishree & Pradhan, Keerti & Kapoor, Smita & Tripathi, Shailesh & Bhattacharya, Sudip. (2024). Unleashing the power of Virtual Reality to manage LAZY EYE-A silent public health problem: A case study from India. Indian Journal of Community Health. 35. 10.47203/IJCH.2023.v35i04.024.
31. Convergence Insufficiency Treatment Trial Study Group (2008). Randomized clinical trial of treatments for symptomatic convergence insufficiency in children. *Archives of ophthalmology (Chicago, Ill. : 1960)*, *126*(10), 1336–1349. https://doi.org/10.1001/archopht.126.10.1336
32. CITT-ART Investigator Group (2019). Effect of Vergence/Accommodative Therapy on Reading in Children with Convergence Insufficiency: A Randomized Clinical Trial. *Optometry and vision science : official publication of the American Academy of Optometry*, *96*(11), 836–849. https://doi.org/10.1097/OPX.0000000000001442
33. Tappeiner C. (2025). Artificial Intelligence in Ophthalmology: Acceptance, Clinical Integration, and Educational Needs in Switzerland. *Journal of clinical medicine*, *14*(17), 6307. https://doi.org/10.3390/jcm14176307
34. Thakur, Renu & Gangta, Jyoti. (2025). Artificial Intelligence-Driven Vision Therapy for Cerebral Visual Impairment in Remote Settings: A Three-Year Follow-Up Case Report: Doi: 10.36351/pjo.v41i2.1908. Pakistan Journal of Ophthalmology. 41. 10.36351/pjo.v41i2.1908.
35. Wang, Pengbo & Wang, Aodi & Wang, Saidi. (2025). Integrating multimodal AI technologies for sports injury prediction and rehabilitation: Systematic review. Journal of Human Sport and Exercise. 21. 22-37. 10.55860/w6j5wc21.
36. Wygnanski-Jaffe, T., Moshkovitz, A., Kushner, B. J., Belkin,

M., Yehezkel, O., & CureSight Pivotal Trial Group (2024). Binocular Home Treatment for Amblyopia: Gains Stable for One Year. *American journal of ophthalmology*, *262*, 199–205. https://doi.org/10.1016/j.ajo.2024.02.004

37. 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., & Luminopia Pivotal Trial Group (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

38. Li, Changli & Li, Fangfang & Zhang, Kao & Chen, Nenglun & Pan, Zhigeng. (2025). Gaze Estimation Network Based on Multi-Head Attention, Fusion, and Interaction. Sensors. 25. 1893. 10.3390/s25061893.

39. Jing, Y., Li, L., Li, Z., Zhou, T., Zhu, X., Shen, S., Guo, W., Leng, Z., Fan, Y., Guo, K., Zhang, L., Lang, L., Xu, L., Liu, H., & Zhu, H. (2026). Virtual Reality-Based Vision Therapy for Intermittent Exotropia: A Randomized Clinical Trial. *JAMA network open*, *9*(3), e260631. https://doi.org/10.1001/jamanetworkopen.2026.0631