BYNOCS®1 – A Cloud-Based Indigenous Tele-Health Vision Therapy Software for the Assessment and Management of Binocular Vision Disorders

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ARTICLE

BYNOCS®[1] – A Cloud-Based Indigenous Tele-Health Vision Therapy Software for the Assessment and Management of Binocular Vision Disorders

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ABSTRACT

Background

Binocular vision assessment is an integral part of an eye and vision care practice. With the need for a user friendly, simplified, and comprehensive tool especially in this digital era, we propose a new indigenous cloud-based software, Bynocs.® This manuscript describes the technical details, the functioning of this indigenous software, and a case series demonstrating the application and efficacy of Bynocs® as a tele-health vision therapy tool. All the three cases were handled remotely through the Bynocs tele-health vision therapy platform.

Case Reports

Case 1: This is a case of symptomatic convergence insufficiency who had prior compliance issues with a conventional vision therapy approach. With 10 sessions of Bynocs vision therapy focused on improving convergence amplitudes, the patient showed significant improvements in both subjective and objective parameters.

Case 2: This case is of a 12 year old child with residual anisometropic amblyopia who had excellent compliance with patching therapy for 3 years but visual acuity had plateaued over the last 6 months. After 20 sessions of Dichoptic amblyopia therapy, best-corrected visual acuity (BCVA) improved by 3 log MAR lines, with improvements in stereoacuity to 100 sec of arc.

Case 3: This case of a 10 year old child with residual exophoria after strabismus surgery was referred for managing the residual deviation and associated visual complaints. The child had 20/20 visual acuity in both eyes and 10 prism diopters of residual exophoria at distance and near. After 30 sessions of vision therapy, improvements in fusional vergence amplitudes was achieved along with the deviation restoring to orthophoria at both distance and near, with further improvements in stereoacuity from 400 sec of arc to 120 sec of arc.

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Keywords: Bynocs, Software, Tele-Health, Vision Therapy

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Conclusions

As tele-health is finding favor across the globe, Bynocs® can be a valuable tele-health vision therapy tool for in the management of binocular vision anomalies and amblyopia with the functionality for remote diagnosis and therapy.

BACKGROUND

Binocular vision being an integral part of eye and vision care also demands considerable expertise with limited tools available for objective assessment, therapy and follow-up. During this COVID-19 era, this is more relevant now with the demand for remote diagnosis, management and follow-up. Management of binocular vision disorders requires a set of standard ophthalmic equipment and tools, and some of them being available on the digital platforms. But to the best of our knowledge, there is a lack of availability of indigenous tools for remote diagnosis and treatment of binocular vision anomalies on a single digital platform. To overcome these limitations, the study group indigenously developed a cloud-based comprehensive binocular vision assessment and management software called BYNOCS® that was officially released in August, 2018. Bynocs® has a user friendly interface that can be conveniently used as a tele-health vision therapy program, and allows an Optometrist, Orthoptist or Vision therapist to remotely conduct diagnostic tests like assessment of visual acuity, measurement of heterophoria, accommodation facility, fusional vergence and stereopsis for distance and near. Bynocs® also has programs to carryout vision training activities for accommodation, fusional vergence and dichoptic based anti-suppression therapy for the management of amblyopia. The software can function on any computer or laptop with a LED screen size of 11" or more with internet connectivity.

Table 1. Unique features of Bynocs® – the tele-health vision therapy

Features	Functions
Diagnostic modules	
LogMAR visual acuity chart (high and low contrast)	Randomly generated test optotypes result in more reliable visual recording.
Heterophoria	Measures horizontal, vertical and cyclo-deviation.
Accommodation functions	Measures accommodation facility with the hand speed correction factor incorporated to provide more accurate results compensating for the motor response.
Fusional Vergence (Divergence & Convergence)	Dynamic random dot patterns gives more accurate results as both the peripheral and central fusion cues change. This gives measurements under true dissociated conditions.
Stereopsis for distance and near	Random dot generation prevents fusion lock. Incorporation of inter pupillary distance for the calculation of the disparity, aids in accurate estimation of stereopsis.
Worth four dot test for distance and near	Measurement of the size of the suppression scotoma along with the diagnosis of the type of diplopia can be carried out. As the colour of the anaglypgh goggles are calibrated by the software, there are no false negative results.
Anisekonia inspector	Measurement of meridional Anisekonia .
Diplopia charting	Quantifies both primary and secondary deviation in all positions of gaze.
Saccades and Pursuits	Dichoptic stimulation based testing that demands binocular coordination.
Visual Memory	Aids in perceptual assessment as an additional tool in amblyopia diagnosis.
Therapeutic modules	
Vergence and Accommodation therapy	Features such as optimized fusion training and hand speed response factor compensated accommodation facility gives optimum results.
Dichoptic amblyopia therapy	Dichoptic stimuli with automated change in size, frequency and speed of the target along with changes in the crowding environment, give superior results. Presence of multiple game options with various difficulty level makes it more interesting and compliant. These programs not only aim at improving the visual acuity but also to improve fusion and stereopsis.

This manuscript highlights the key features of Bynocs® which includes the 11 diagnostic tools and 3 therapeutic modules (Table 1).

METHODS

In August 2016, one of our authors [MAO] explored the option of developing an indigenous program as there was a huge demand for the same in the country. In discussion with clinical experts, a coder was hired to write four modules namely asthenopia scoring fusional vergence module, phoria module and accommodation module. The programs were coded using Matlab (version 9.3). The beta version was ready by January, 2018 for validation purposes. After seven months, the software was adequately tested for a general release in August 2018.

Construction of tests: An html based visual acuity chart is projected on to the patients screen and then calibration is done for the pixilation of that device. Based on pixilation calibration, a Log MAR chart with randomly generated optotypes is used to test visual acuity at a 2 meter distance from the screen. Near Stereo test chart is constructed for 40 cm distance and the distant chart for 3, 4 and 6 meters. The intermediate distance testing for stereopsis has been added to evaluate stereopsis in conditions such as intermittent divergent exotropia and in patients who prefer monovision corrections.

Based on the input interpupillary distance (IPD) value and the test distance, the displacement of the test plates gets adjusted for fixed disparity values beginning from 2500 sec of arc, to 50 sec of arc. The fusional vergence testing is carried out using random dot stereograms generated to create crossed and uncrossed disparities of magnitudes estimated based on the separation between the stimuli and the testing distance. The heterophoria measurement is carried out at 40 cm.

During the validation phase, estimation of normative data was carried out on 1000 subjects in the age range of 18-35 years for

Table 2. Cut-off points for binocular vision parameters used in the Bynocs® software.

Test Parameter	Observed Values	Interpretation
Asthenopia Score (See Appendix)	8 to 12	Normal
	13 to 20	Mild Asthenopia
	21 to 28	Moderate Asthenopia
	29 to 40	Severe Asthenopia
Heterophoria (at 40 cm)		
Horizontal	Ortho to 4 exo	Normal
	Any Eso or greater than 4 Exo	abnormal
Vertical	Up to 1 hyper or hypo	Normal
	Greater than 1 PD	abnormal
Accommodation Facility with +1.50 DS/ -1.50 DS (at 40 cm) –in cycles per minute	8 and above	Normal
	6 to 8	Borderline
	Less than 6	Abnormal
Fusional Vergence (Divergence) at 40 cm	Break : ≥ 12 PD Recovery: ≥ 8 PD	Normal
	Break : < 12 PD Recovery: < 8 PD	Abnormal
Fusional Vergence (Convergence) at 40 cm	Break : ≥ 30 PD Recovery: ≥ 20 PD	Normal
	Break : < 30 PD Recovery: < 20 PD	Abnormal

binocular vision parameters (Table 2). The tool is also continuously being updated to include newer diagnostic and therapeutic requirements. Bynocs® enables the clinician to conduct the diagnostic tests and administer vision therapy protocols both in the clinic and through the tele- health VT platform.

System requirements: The software functions best on a LED screen with a size more than 11 inches (preferably 32”), and also require uninterrupted internet connectivity with a minimum speed of 512kbps and a recently upgraded Google chrome browser. For the clinical testing, the program requires a universally fitting anaglyph goggles (red-blue or red-cyan), and an accommodative flippers (binocular flippers +1.50 DS/-1.50 DS). A one-

time calibration of size and colour is required to calibrate the anaglyph for true dissociation.

Functioning of Bynocs as a Tele-health Vision Therapy Tool

Being a cloud-based program, Bynocs® has a user friendly interface that can be conveniently used as a tele-health vision therapy program, and allows an optometrist, orthoptist or vision therapist to remotely conduct diagnostic tests and execute therapeutic activities. The practitioners and patient can get connected through browser based video communication platforms like Google Meet, Microsoft Teams, doxy.me or Zoom. Once the patient demographics is added to the portal, the patient receives a link to run the diagnostic tests. During the diagnostic process, practitioners can share their screen to the patient and one time calibration is done for the patient's device through a guided instruction process. This calibration process is very simple in nature and remains saved for that specific browser. Following the calibration, diagnostic tests are performed and the patients' response gets captured in the program for both the patient and the practitioner to view. During the therapeutic session, patients log in to their portal and run the therapy programs as customized by the practitioner based on the specific diagnosis.

The initial sessions are monitored by the practitioner or therapist using the same process as detailed above. The only difference between an in-office based and remote vision therapy is the virtual nature of the interaction.

Unique Features of the Software

Bynocs has tools for accurate calibration of the screen size and colour contrast, thus it can be easily used for cloud based remote sessions. In other cases, calibration is usually carried out on the practitioners computer, thus when screen is shared, the accuracy of the program gets affected. Our aim was to build an indigenous affordable tool with valid scientific principles offering remote diagnosis and treatment for both binocular vision dysfunctions and amblyopia. This in itself is a unique aspect to the Bynocs software.

Apart from this, there are multiple additional features in both the diagnostic and therapeutic modules. In heterophoria measurement, the program can additionally check cyclo deviation in all cardinal position of gazes. The software introduces a feature characterized by the change in the presentation of the random dots for both the peripheral and central stimuli. This avoids the erroneous high fusional vergence amplitudes through resetting the fusion cues during every presentation and yields vergence amplitudes under most dissociated conditions increasing the sensitivity to diagnose Nonstrabismic binocular vision dysfunctions.

In accommodation facility measurements it is known that the speed of response due to familiarity with the keyboard, and cognitive load independent of the accommodative response can impact the measurements. This is taken care of as the accommodative facility measurements are calculated compensating for the speed of the response measured by the software based on the hand speed response.

The retinal disparity measurements used to calculate stereopsis for both distance and near based on interpupillary distance is accurately captured. The software is optimized for the most comprehensive dichoptic treatment protocol for anti-suppression, fusion and stereopsis training. The software also has an ETDRS logMAR chart calibrated for various testing distance, randomized for each eye. This also assists the clinicians in visual acuity measurements to understand the visual prognosis in amblyopia under remote care. The Anisekonia measurements can help the clinician to decide about the best optical modality in case of anisometropia.

CASE STUDIES

Case 1: A 28 year old female, software engineer by profession called for a consultation with complaints of headache and eye strain while working with computers. Previous ophthalmic examination showed no refractive error, and the patient gave a history of undergoing vision therapy 1 year back, that she had discontinued later due to time constraint. Patient was tested on the Bynocs® diagnostic module via zoom platform. Visual acuity recorded was 20/20 in both eyes, worth four dot test showed no suppression; distance and near stereopsis was 70 and 50 seconds of arc respectively, and had 1.5 PD exophoria at near. Patient had a score of 28 (Normal values: 12 or less) on the Bynocs® asthenopia questionnaire. Her accommodation facility with +/- 1.50 DS flipper was 12 cpm, near fusional divergence (break/ recovery) was 12/10 prism diopters (PD) (Expected values: 10/8), and the near fusional convergence showed reduced break/ recovery value of 10/6 PD (Expected values: 30/20 PD).

Based on the clinical parameters, the patient was diagnosed with Convergence Insufficiency, and was provided with 10 sessions of remote vision training. Each therapy session lasted for 30 minutes, and a minimum of 4 sessions were provided every week during the initial phase. The sessions comprised of training for accommodative facility (5 min), smooth fusional divergence (5 min), jump fusional divergence (5 min), smooth fusional convergence (7 min), and jump fusional convergence (7 min).

During the review after 10 sessions, there was a significant improvement in both subjective and objective measures of binocular vision. The patient was asymptomatic with an asthenopia score of 8, and the near convergence amplitudes improved to 30/24 PD. The near exo reduced to 0.5 PD with improvements in accommodation facility to 16 cpm. She was advised to continue with the

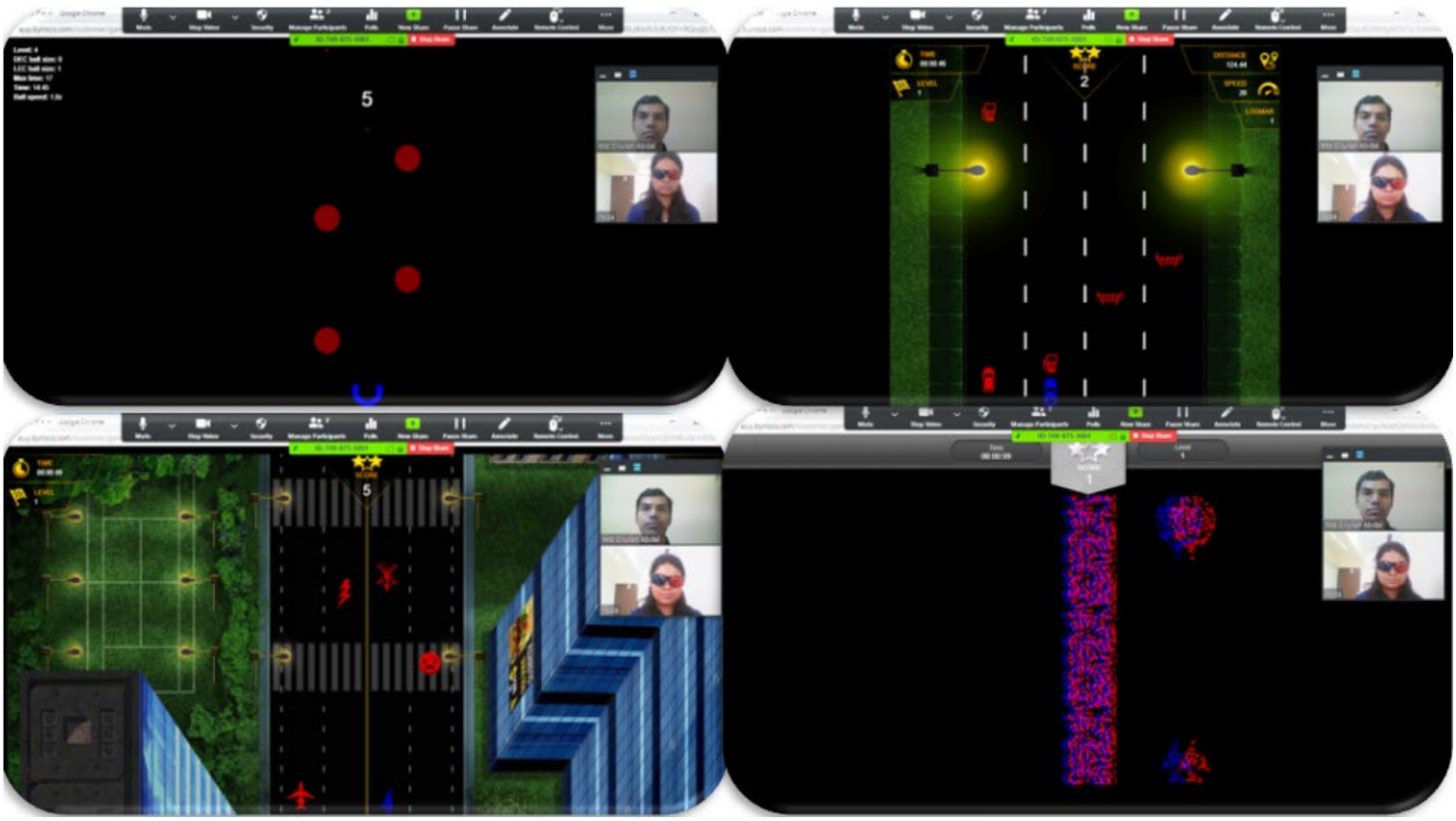

Figure 1: Screenshot of dichoptic games (not representative of the actual image resolution) namely SuperBall, SuperCar, SuperMan and Super3D as the practitioner connects with the patient through remote video call and monitors the performance through screen sharing. The same process is utilized for diagnosis and therapy.

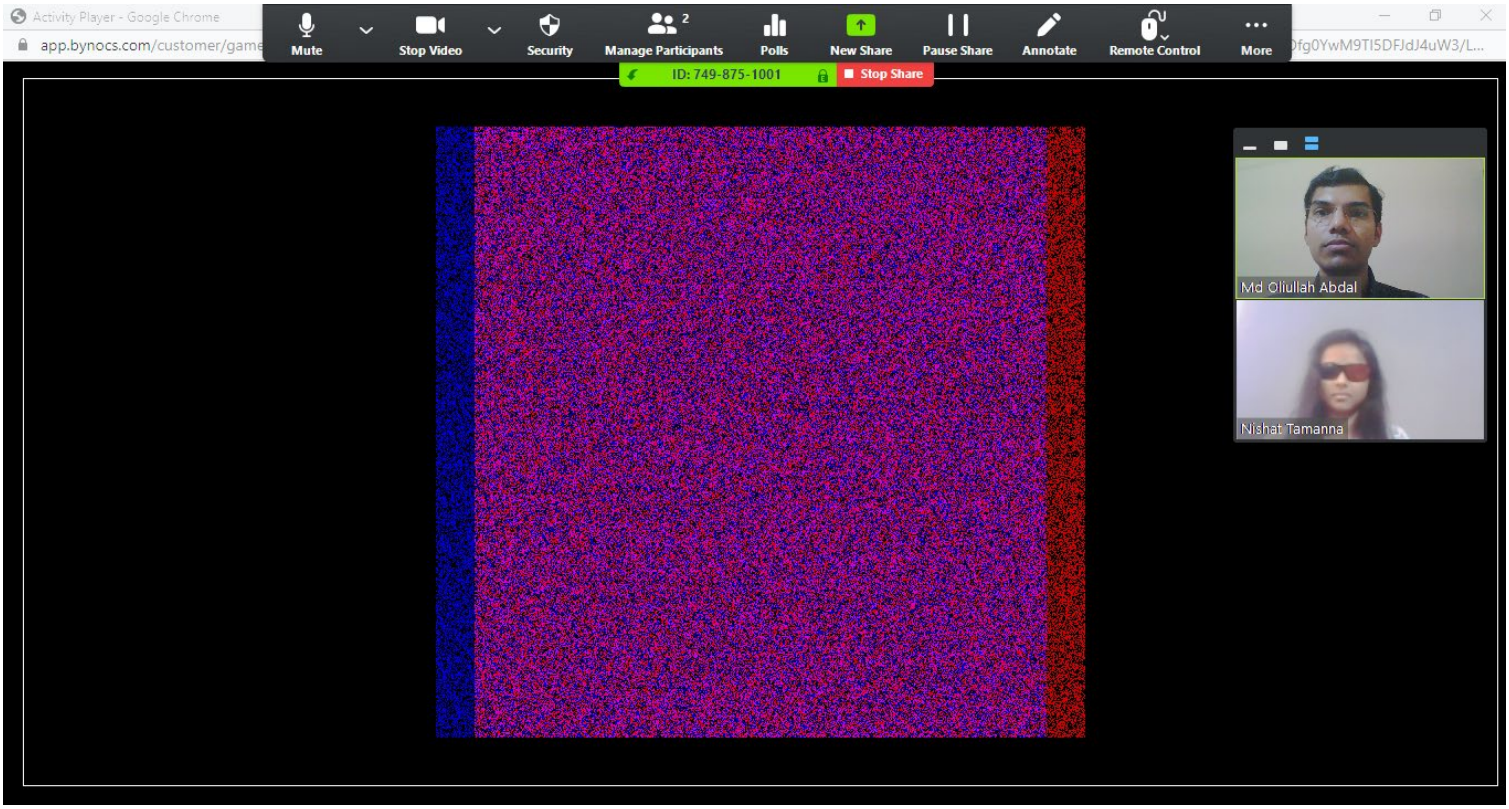

Figure 2: Screenshot of fusional vergence game (not representative of the actual image resolution) as the practitioner connects with the patient through remote video call and monitors the performance through screen sharing. The same process is utilized for diagnosis and therapy.

vision therapy with twice a week maintenance protocol to avoid further relapse. A review after 3 months has been advised.

Case 2: A 12 year old patient diagnosed with anisometropic amblyopia consulted our team for dichoptic amblyopia therapy (DAT). She was wearing a refractive correction of Plano in the right eye and +3.00 DS in the left eye. Her cycloplegic refraction showed +1.00 DS and +4.00 DS in the right and left eye respectively, and she preferred the same refractive correction that she has been using.

She was on part time occlusion for 6 hours a day for the last 3 years and her reports showed a plateauing of visual acuity over the last 6 months. The patient was contacted through Zoom platform and was counselled about dichoptic therapy in Bynocs® therapeutic module. Patient's best corrected visual acuity was 20/ 20 in the right eye and 20/80 in the left eye, showed suppression of the left eye in the distant worth four dot test, and the distance and near stereopsis was absent on Bynocs® Diagnostic module. Based on the history and findings, patient was started with Bynocs® dichoptics amblyopia therapy protocol.

The patient underwent 10 sessions of anti-suppression exercises with the aim of breaking suppression and improving gross stereopsis to be able to continue with the DAT protocol. The DAT protocol uses targets that has stereopsis ranging from 2500 to 50 arc seconds.

This consisted of four dichoptic games that included the SuperBall, SuperCar, SuperMan and Super3D along with fusional exercises (Fig. 1).

A repeat evaluation after 20 sessions (45 minutes/ session) showed a three lines improvement in visual acuity along with fusion at near, and improved Stereo acuity of 100 seconds for arc at distance and near. She has been advised to continue with the DAT vision therapy program and a review is being recommended at 3 months.

Case 3: A 10 year old child with history of strabismus surgery for exotropia 3 years back consulted our team for vision therapy to improve fusion and stereopsis. She has started

to show residual exodeviation associated with asthenopic symptoms.

On remote testing, visual acuity was recorded as 20/20 in both eyes, 10 PD exophoria at distance and near, near stereopsis of 400 seconds of arc and absence of distance stereopsis. Based on the clinical findings, patient was administered the Bynocs® DAT therapeutic protocol consisting of four dichoptic games, SuperBall, SuperCar, SuperMan and Super3D (Fig. 1) along with Fusional exercises (Fig. 2).

Each session lasted for 60 minutes, and 5 sessions a week were provided over a period of 6 weeks. A repeat evaluation after 30 sessions revealed orthophoria at distance and near, with improvements in stereoacuity to 120 seconds for arc at distance and 50 seconds of arc at near. The asthenopia scores improved from 28 pre vision therapy to 10 post vision therapy. A follow-up has been advised at 3 months with a maintenance schedule of 2 sessions every week.

DISCUSSION

This article intends to bring out the role of tele-health vision therapy[1] in this COVID-19 era where both binocular vision assessment and vision therapy can be handled using tools such as the Bynocs.® Bynocs® is a uniquely designed software for the assessment and management of binocular vision disorder. Being hardware agnostic and cloud-based, it can fit inside every Optometric practice. The only requirement is a computer or laptop with a minimum LED screen size of 11 inches, a pair of anaglyph glasses and flippers. This validated software is built so that it is easy to use with a very short learning curve.

Vision therapy that started in the late 19th century as a non-invasive approach to managing strabismus later became a standard of care as the treatment for a wide range of binocular vision anomalies. As the understanding and the evidence based practice in vision therapy gained its momentum into the 21st century, computer based vision therapy started to play an important role in clinical practices. The convergence insufficiency treatment trial (CITT)[2] established the evidence for in-office vision therapy through its well conducted randomized clinical trial. This prospective, multicentric, double blind RCT established the efficacy of office based vision therapy (OBVT) with home reinforcement as the best treatment for convergence insufficiency over other existing conventional approaches including the pencil push-up exercises. The CITT trial also emphasized the need for patient engaging activities using computer based vision therapy approaches as an opportunity to improve patient compliance as the key component driving improvement in any treatment regimen. With these foundational principles in practice, Bynocs serves as a valuable tool for the clinician to provide vision therapy using a robust model of tele-health vision therapy. The way tele-health vision therapy is done through Bynocs makes the remote session equivalent to the office based vision therapy (OBVT) session because of the direct interaction between therapist and patient during the entire session via screen sharing and monitoring. Case 1 and 3 demonstrates the application of this tool in the management of Nonstrabismic binocular vision anomalies.

In the amblyopia management world, things are evolving rapidly moving away from conventional patching to binocular modalities of treatment. The optometric vision therapy approach in amblyopia has always emphasized the need for binocular training as a glue to improving fusion and sustaining the improvements achieved in monocular visual functions. The primary goal in a vision therapy program in amblyopia is to eliminate suppression using the monocular fixation in a binocular field technique (MFBF).[3] Using this foundational approach, Bynocs uses a Dichoptic based therapy platform that engages the patient using three active game based

vision therapy strategies. An ongoing RCT from the study team is exploring the efficacy of this option over the existing conventional approaches for amblyopia treatment. But as logic would predict, such engaging tools drastically improves the compliance and visual functions in parallel. Case 2 demonstrates this in a 12 year old child diagnosed with anisometropic amblyopia with a known history of poor compliance to conventional patching treatment. Within 20 hours of training, the child achieved three lines improvement in visual acuity, with parallel improvements in binocularity. This shows the promising nature of such innovative VT approaches with solid scientific foundations in place. Similar successful results have also been reported in Dichoptic clinical trials especially where the target contrast between the eyes are balanced to enhance the binocular summation of the amblyopic visual system. This strategy has shown promising results in improving both monocular and binocular visual functions and reducing suppression in children and adults with amblyopia.[4-6]

The Bynocs team also provides tele-health vision therapy consultation to the novice clinician who is getting started with their binocular vision practice using the tele-health VT platform. This becomes so valuable in the current COVID-19 world as clinicians are under tremendous stress to rebuild their practices and are also trying to serve the patients who need clinical care. In a country like India, where the prevalence for binocular vision dysfunctions are high,[7] and the demand for clinical care is always on the upsurge, such tools has its place in every eye care practice.

CONCLUSION

As tele-health and tele-health vision therapy is finding favor across the globe, Bynocs® can be a very valuable tool which has the functionality for remote diagnosis and therapy in the management of binocular vision anomalies and amblyopia.

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Appendix

Bynocs Asthenopia Symptom Scoring

1. **On an average how long can you do "near work"(i.e., reading, writing, computer work, digital devices use, etc.) without any visual discomfort?**
   a. at least 3 hours
   b. up to 2 hours
   c. up to 1 hour
   d. up to 30 minutes
   e. up to 15 minutes

2. **How often do you get headaches on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)

3. **If you experience headaches on doing near work, how bothersome are these headaches?**
   a. minimally bothersome
   b. mildly bothersome
   c. moderately bothersome
   d. very bothersome
   e. extremely bothersome

4. **Do your eyes ache on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)

5. **Does the reading material ever become blur on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)

6. **Does the reading material ever become double on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)

7. **Do you have eyestrain on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)

8. **Do your eyes burn on doing near work?**
   a. never (0% of the time)
   b. occasionally (about 25% of the time)
   c. often (about 50% of the time)
   d. very often (about 75% of the time)
   e. every time (100% of the time)