THE DOCTOR WILL “SEE” YOU: VISUAL ASSESSMENT VIA TELEHEALTH

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DISCLOSURES

No relevant financial disclosures or conflicts of interest

LEARNING OBJECTIVES

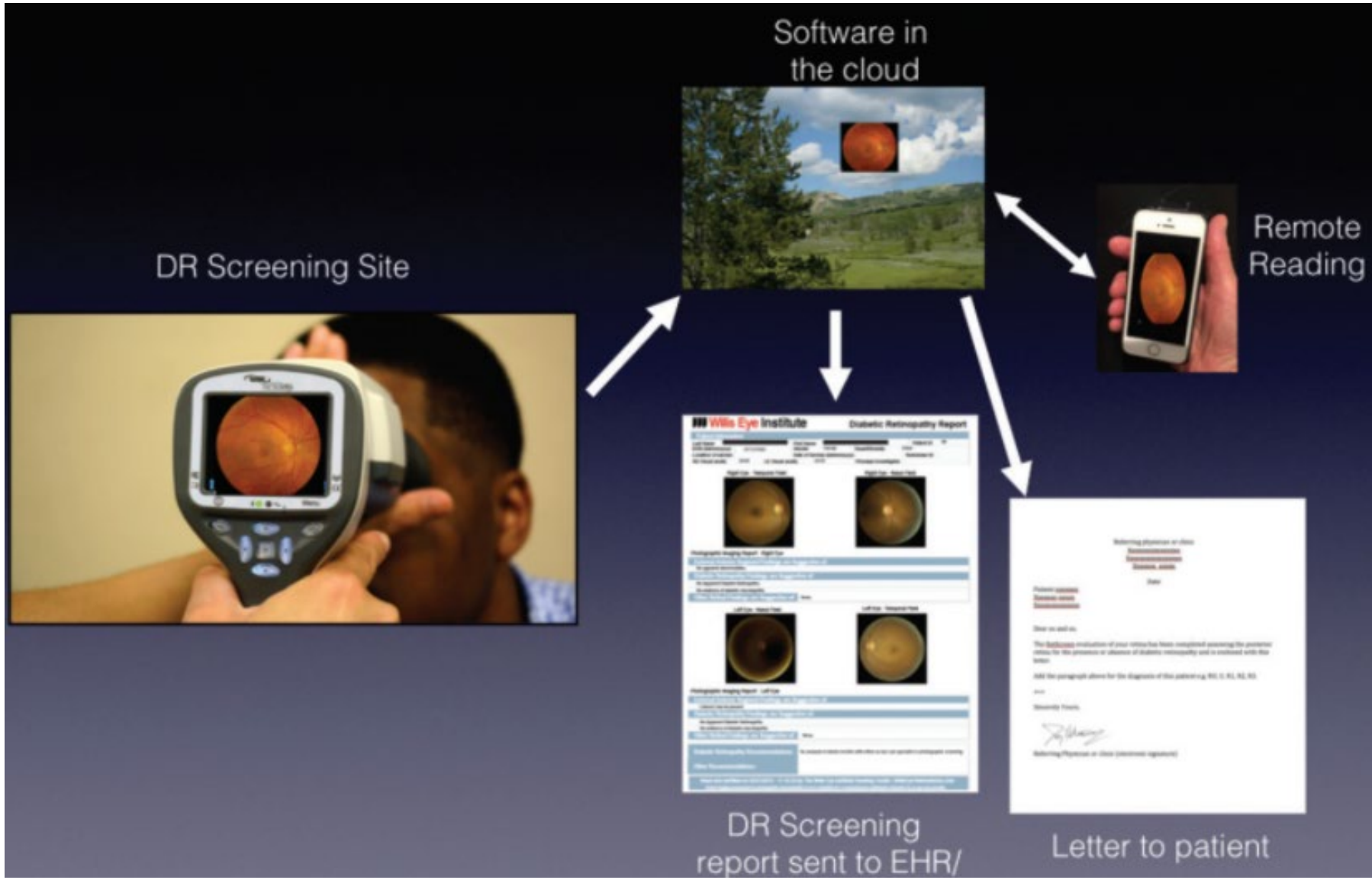
Current State and Needs of Telehealth for Visual Assessment

Current digital testing apps for:

- Visual Acuity
- Visual Fields
- Eye Motility

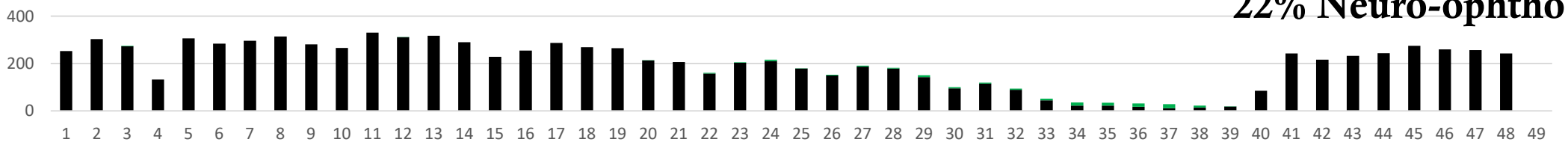
Future State of Telehealth and Visual Assessment

TELE-OPHTHALMOLOGY-PRE-COVID



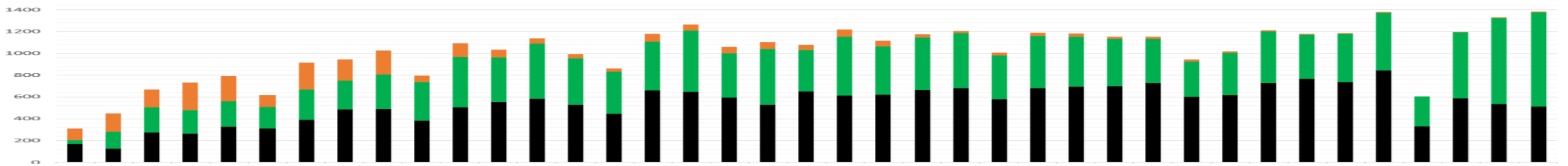
- https://retinatoday.com/articles/2017-apr/telemedicine-in-ophthalmology

A Tertiary Academic Health System



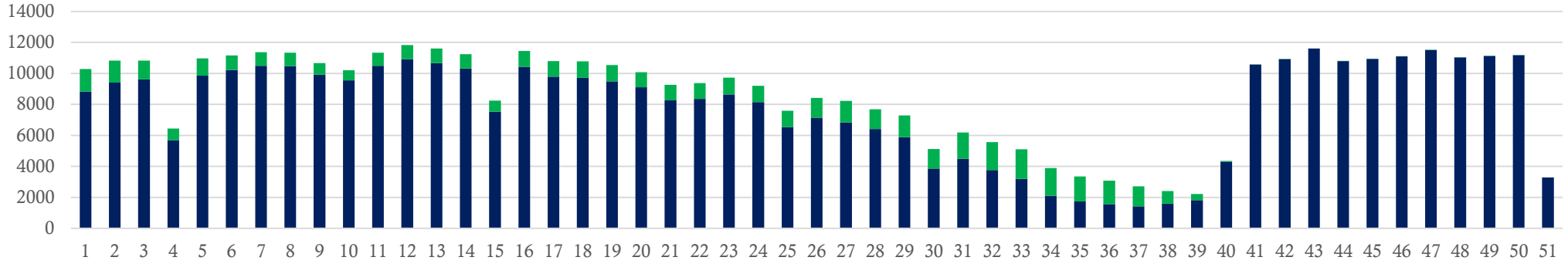
22% Neuro-ophtho

2.7%



62%

All outpatient



11%

Telemedicine Adoption Ophthalmology vs. Neurology vs. All outpatient Visits

1/2020-12/19/2020

Disability Evaluation Under Social Security

2.00 Special Senses and Speech - Adult

2.00 Special Senses and Speech

A. *How do we evaluate visual disorders?*

1. *What are visual disorders?* Visual disorders are abnormalities of the eye, the optic nerve, the optic tracts, or the brain that may cause a loss of visual acuity or visual fields. A loss of visual acuity limits your ability to distinguish detail, read, or do fine work. A loss of visual fields limits your ability to perceive visual stimuli in the peripheral extent of vision.

2. *How do we define statutory blindness?* Statutory blindness is blindness as defined in sections 216(i)(1) and 1614(a)(2) of the Social Security Act (Act).

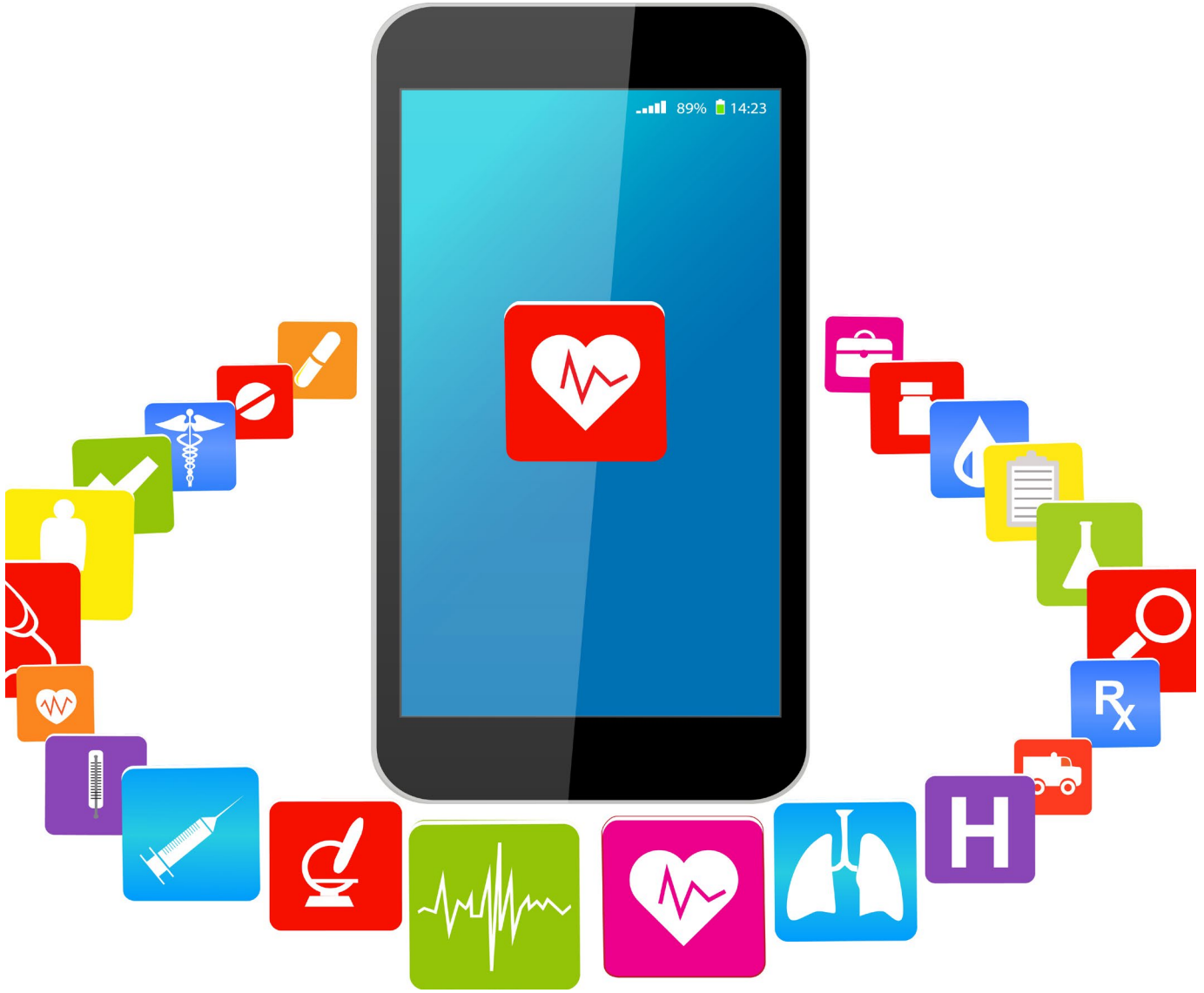
a. The Act defines blindness as central visual acuity of 20/200 or less in the better eye with the use of a correcting lens. We use your best-corrected central visual acuity for distance in the better eye when we determine if this definition is met. (For visual acuity testing requirements, see 2.00A5.)

b. The Act also provides that an eye that has a visual field limitation such that the widest diameter of the visual field subtends an angle no greater than 20 degrees is considered as having a central visual acuity of 20/200 or

HOW DO WE TRANSLATE VISION TESTING TO A VIRTUAL ENVIRONMENT?

VISION APPS ABOUND, BUT...

- Android (270+ apps) and iOS (170+ apps): Most ***not*** suitable for ophthalmic/neuro-ophthalmic telehealth exam
- **•Extremely limited clinical validation**



VISION APP CATEGORIES AVAILABLE

VISUAL ACUITY (NEAR/DISTANCE)

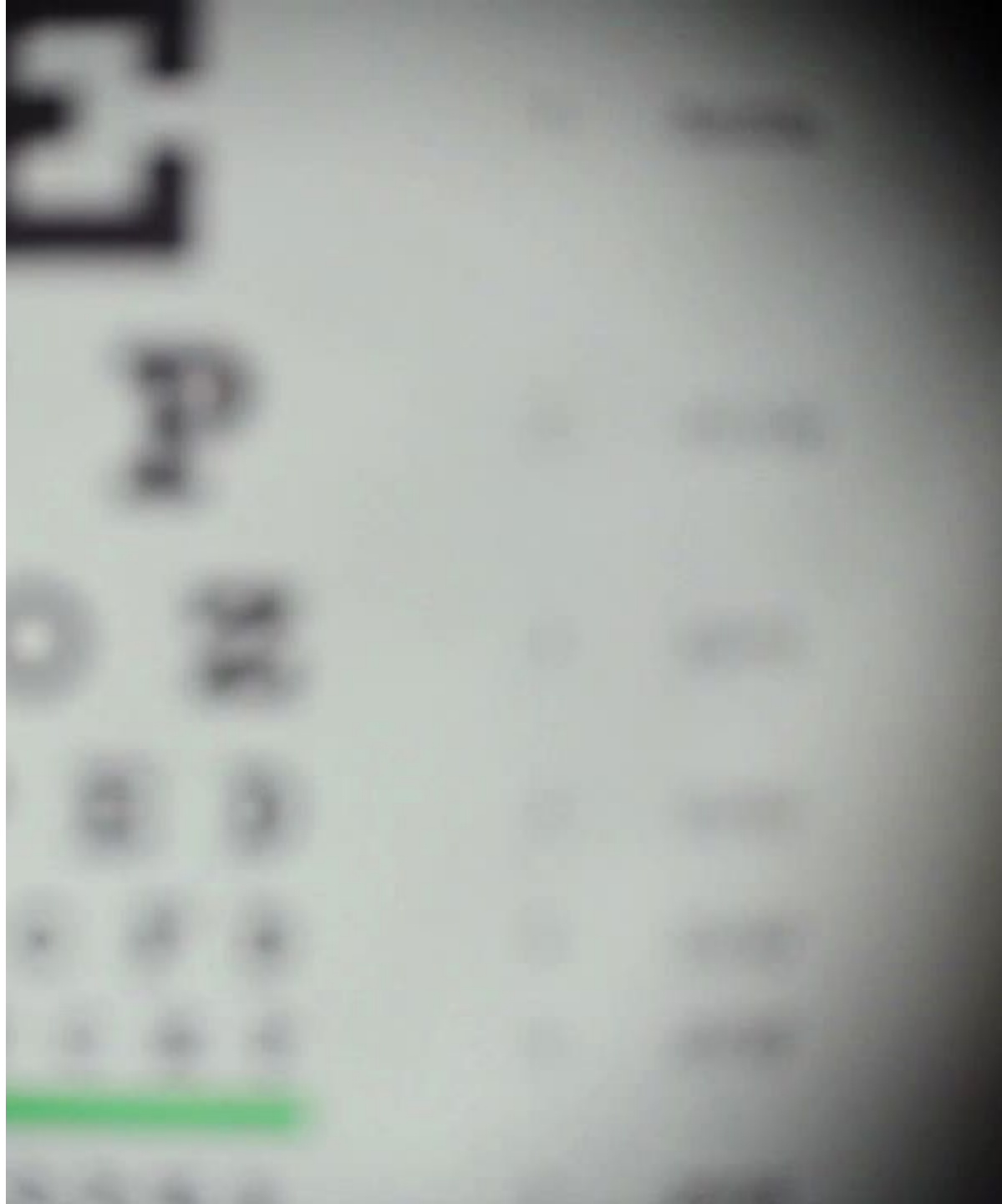
VISUAL FIELDS

EFFERENT EXAMINATION

IS THE VISION APP….

CHARACTERIZED?
THE DESIGNED APP IS REPRODUCIBLE IN EACH DEVICE

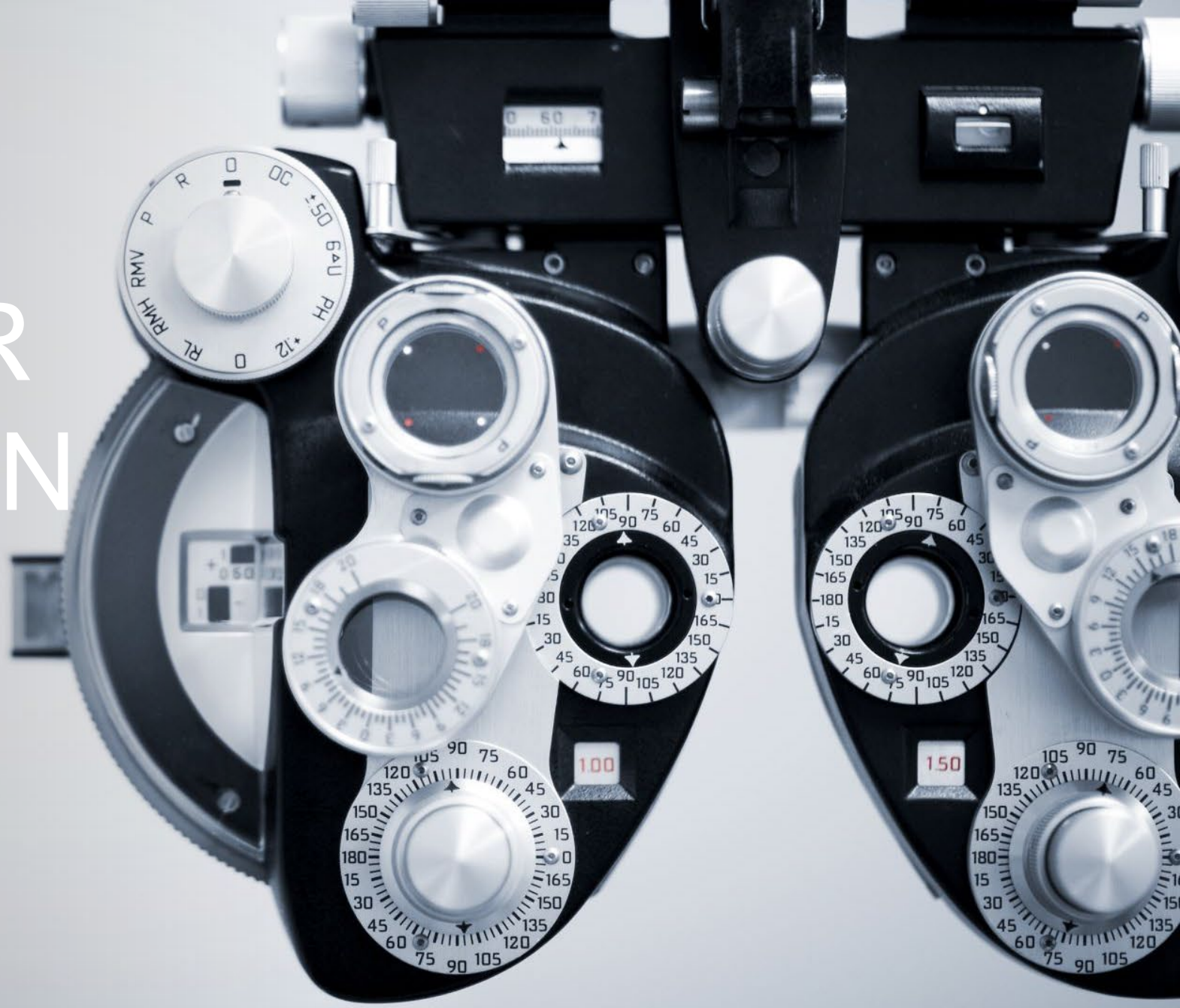
CLINICALLY VALIDATED?
APP MEASURES IN A COMPARABLE MANNER TO MEASURES OBTAINED W/ GOLD STANDARD

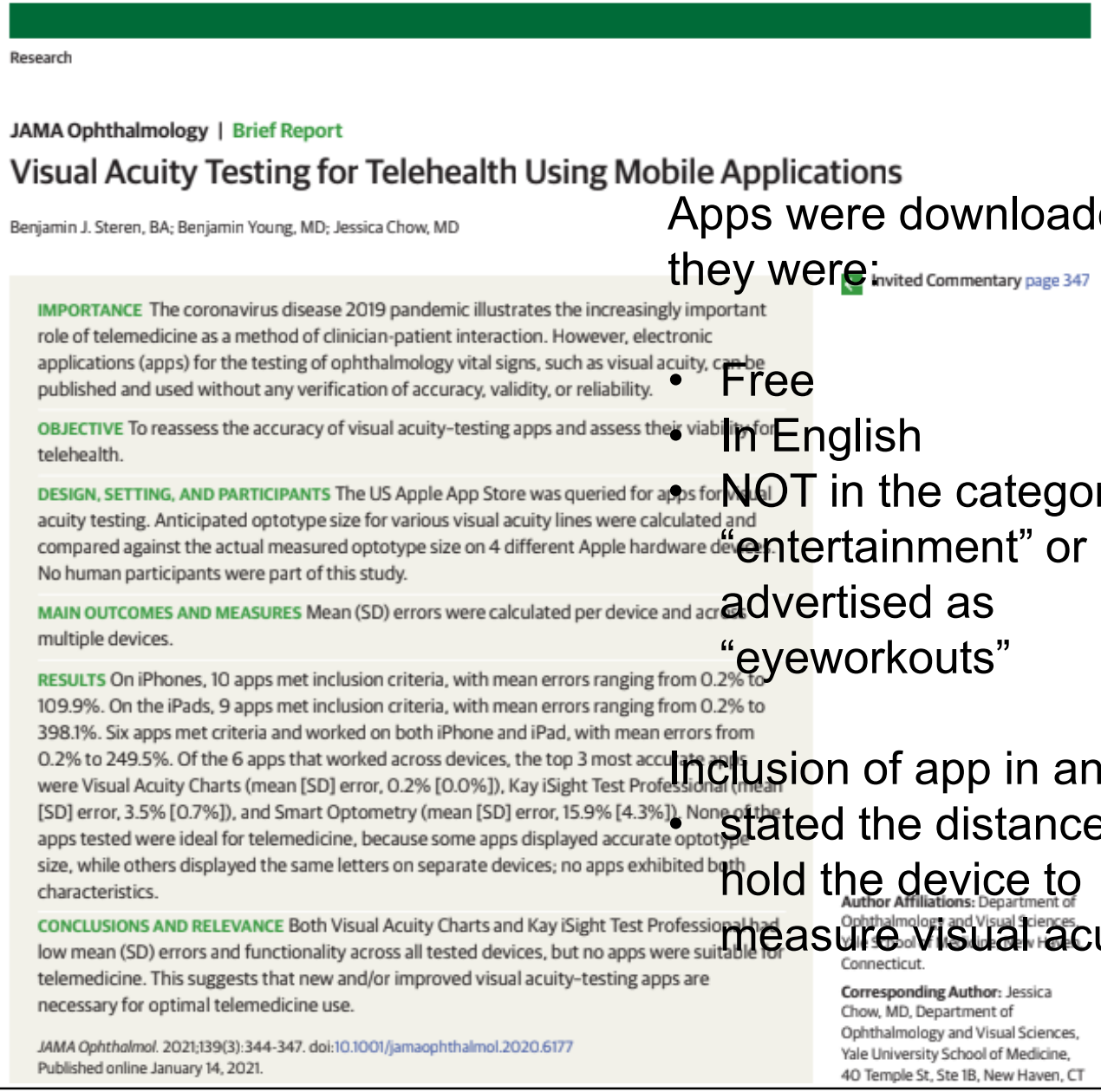


THE PERFECT VISUAL TESTING APP?

- Characterization and Validation on different operating system devices
- Easily accessible, affordable, and available to patients
- Self-administered

VISUAL ACUITY FOR NEAR VISION TESTING





Research

JAMA Ophthalmology | Brief Report

Visual Acuity Testing for Telehealth Using Mobile Applications

Benjamin J. Steren, BA; Benjamin Young, MD; Jessica Chow, MD

Invited Commentary page 347

IMPORTANCE The coronavirus disease 2019 pandemic illustrates the increasingly important role of telemedicine as a method of clinician-patient interaction. However, electronic applications (apps) for the testing of ophthalmology vital signs, such as visual acuity, can be published and used without any verification of accuracy, validity, or reliability.

OBJECTIVE To reassess the accuracy of visual acuity–testing apps and assess their viability for telehealth.

DESIGN, SETTING, AND PARTICIPANTS The US Apple App Store was queried for apps for visual acuity testing. Anticipated optotype size for various visual acuity lines were calculated and compared against the actual measured optotype size on 4 different Apple hardware devices. No human participants were part of this study.

MAIN OUTCOMES AND MEASURES Mean (SD) errors were calculated per device and across multiple devices.

RESULTS On iPhones, 10 apps met inclusion criteria, with mean errors ranging from 0.2% to 109.9%. On the iPads, 9 apps met inclusion criteria, with mean errors ranging from 0.2% to 398.1%. Six apps met criteria and worked on both iPhone and iPad, with mean errors from 0.2% to 249.5%. Of the 6 apps that worked across devices, the top 3 most accurate apps were Visual Acuity Charts (mean [SD] error, 0.2% [0.0%]), Kay iSight Test Professional (mean [SD] error, 3.5% [0.7%]), and Smart Optometry (mean [SD] error, 15.9% [4.3%]). None of the apps tested were ideal for telemedicine, because some apps displayed accurate optotype size, while others displayed the same letters on separate devices; no apps exhibited both characteristics.

CONCLUSIONS AND RELEVANCE Both Visual Acuity Charts and Kay iSight Test Professional had low mean (SD) errors and functionality across all tested devices, but no apps were suitable for telemedicine. This suggests that new and/or improved visual acuity–testing apps are necessary for optimal telemedicine use.

JAMA Ophthalmol. 2021;139(3):344-347. doi:10.1001/jamaophthalmol.2020.6177
Published online January 14, 2021.

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Apps were downloaded if they were:

- Free
- In English
- NOT in the category of “entertainment” or advertised as “eyeworkouts”

Inclusion of app in analysis:

- stated the distance to hold the device to measure visual acuity

Steren BJ, Young B, Chow J. Visual Acuity Testing for Telehealth Using Mobile Applications. JAMA Ophthalmol. 2021 Mar 1;139(3):344-347. doi: 10.1001/jamaophthalmol.2020.6177. PMID: 33443550; PMCID: PMC7809609.

Table. Applications (Apps) With Functionality Across the iPhone and iPad

App name	App version	Publisher	Distance, cm	Average mean (SD) error, %
Visual Acuity Charts	2.5	Zijian Huang	400	0.20 (0.00)
Kay iSight Test Professional	2.1	Kay Pictures Limited	40	3.50 (0.70)
Smart Optometry	4.0	Smart Optometry DOO	40	15.90 (4.30)
EyeTesterFree	1.5	FISP Precision Co Ltd	100	18.90 (13.30)
Eye Handbook	8.2.12	Cloud Nine Development, LLC	35	28.00 (27.40)
Vision Scan Lite	1.3	Cygnet Infotech, LLC	60.96	249.50 (130.80)

VISUAL ACUITY APPS: NEAR VISION TESTING

KAY ISIGHT TEST PRO

First Month Free, then by paid subscription Service

Works on iphone or iPad

Self Administer

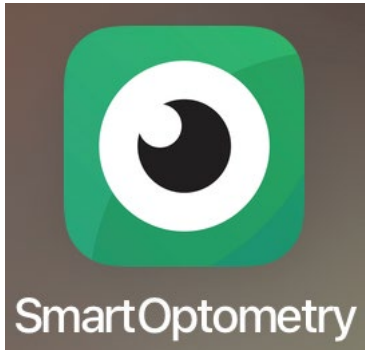
Tests between 20/250 down to 20/10

Optotypes for children available

3 meters/~10 feet

VISUAL ACUITY APPS: NEAR VISION TESTING

SMART OPTOMETRY



Iphone/iPad

Free version only optotype choices of Landolt C's or Tumbling E's

Testing at 40 cm (15.7 in)

VISUAL ACUITY APPS: NEAR VISION TESTING

Eye Handbook

Lord, Shah, Krishna. Mo Med (2013)

Benefits

- All-in-one App (VA, Amsler, Ishihara, Red Sat., Peds)
- Available on Android and iOS
- Free
- Self administration, near at 36 cm (1 ft. 2 in)

Caveats

- Overestimates near VA (0.11 LogMAR or 1-line Snellen).
  - Tofig et al., Eye (2015).
- iOS optotypes consistent, but *Android are randomized.*

CONCLUSIONS AND RELEVANCE Both Visual Acuity Charts and Kay iSight Test Professional had low mean (SD) errors and functionality across all tested devices, but no apps were suitable for telemedicine. This suggests that new and/or improved visual acuity–testing apps are necessary for optimal telemedicine use.

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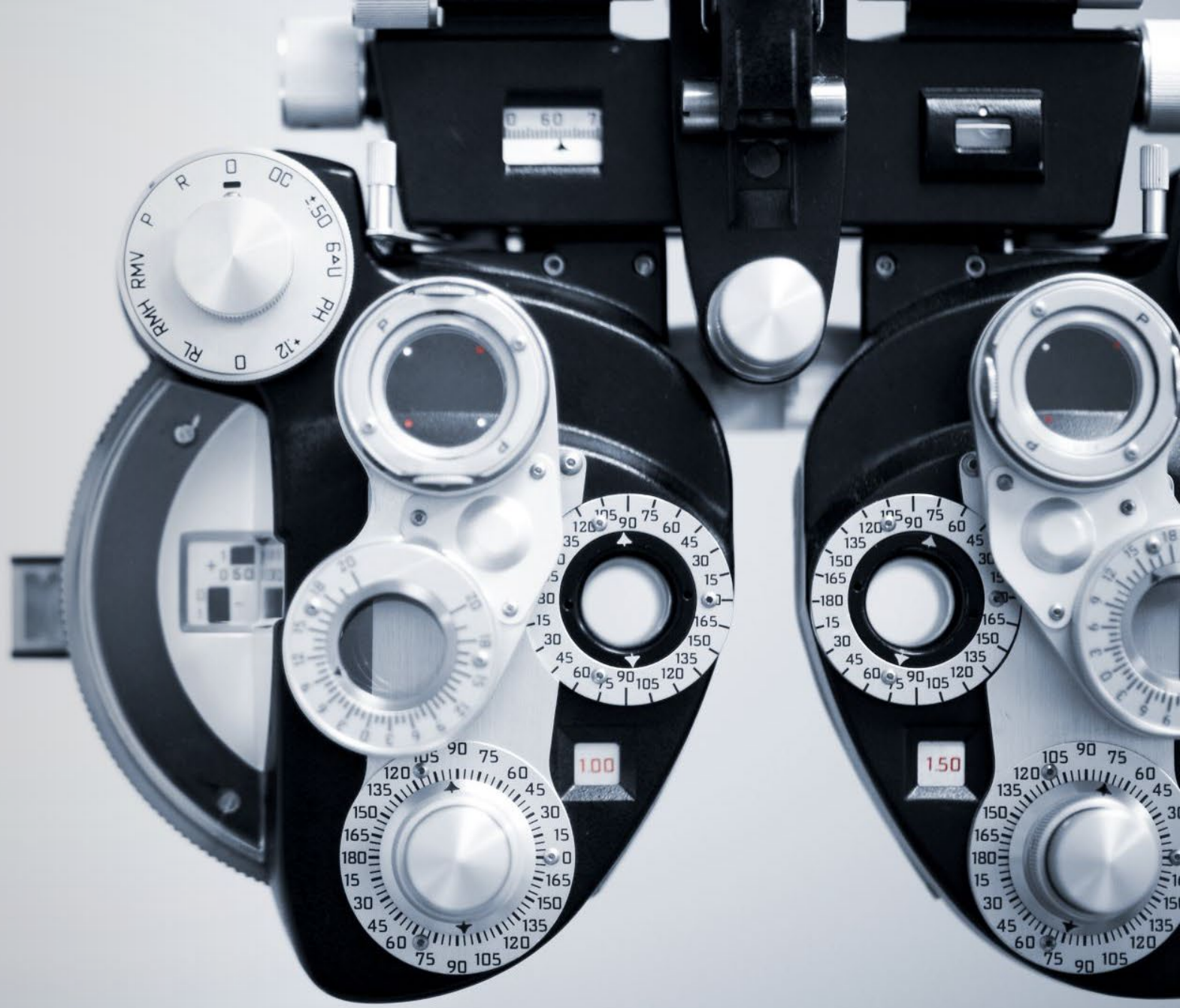
Published online January 14, 2021.

VISUAL ACUITY FOR DISTANCE VISION TESTING

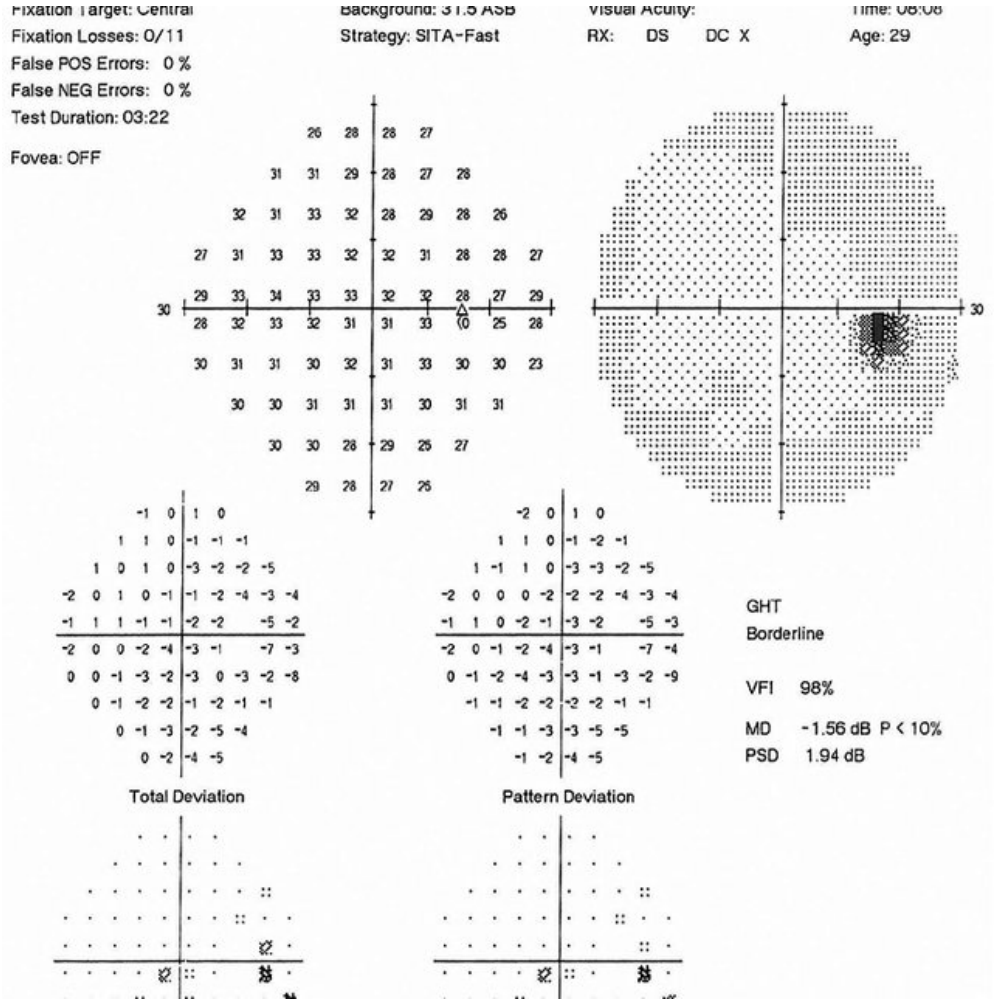


DISTANCE VISUAL ACUITY

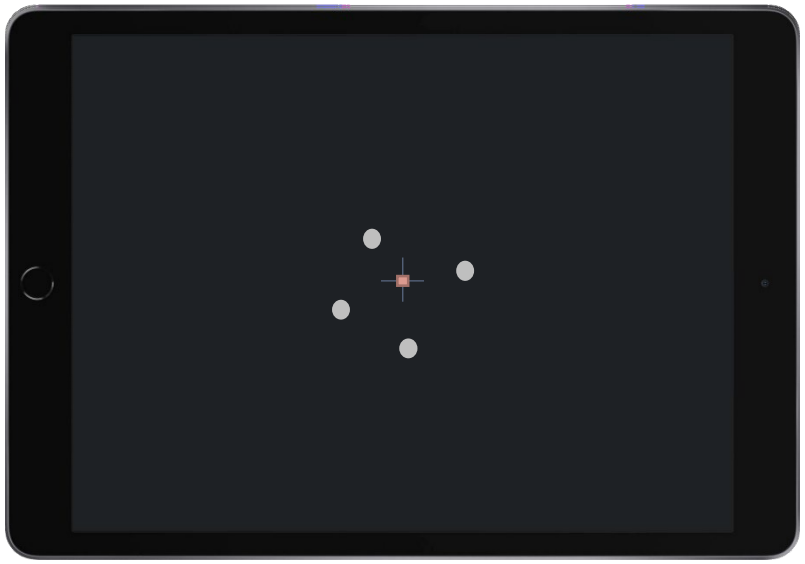
- AAO has printable Snellen charts for adults and Tumbling E’s for children on their website, read at 10 ft.

- Mailing chart to patient may be the best option – work with a professional printing company.

PERIPHERAL VISION TESTING



VISUAL FIELD TESTING AT HOME: "MELBOURNE RAPID FIELDS"



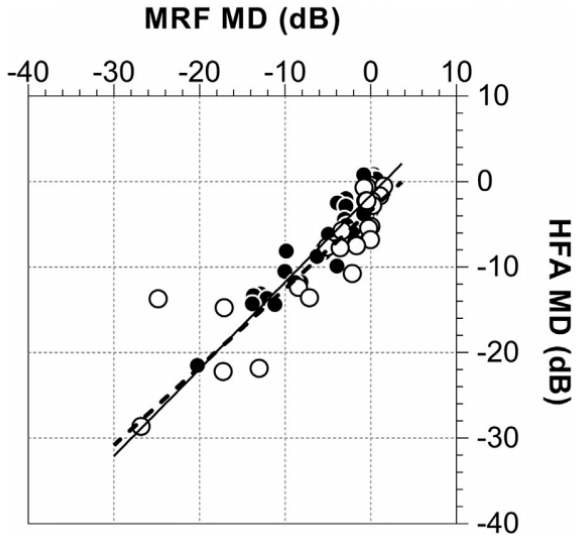
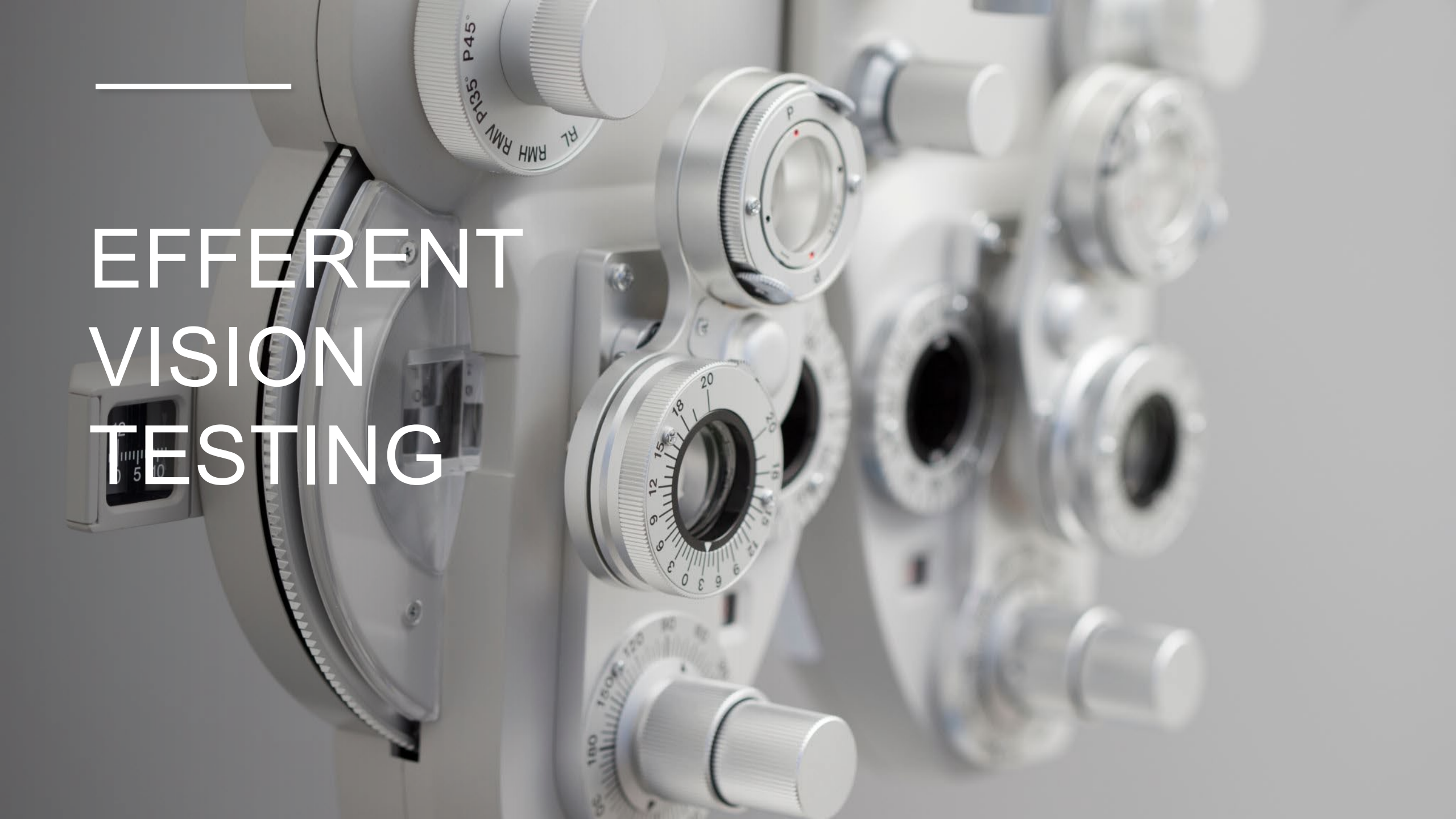


FIGURE 4. Association between the Humphrey Field Analyzer mean deviation (MD) and the corrected Melbourne Rapid Fields MD averaged over all tests that the patient attended. Unfilled circles (dotted line) show SITA-fast data and filled circles (black line) show SITA-standard. Regression lines are as follows: SITA-fast, $y = 0.92 \pm 0.11*x - 3.4 \pm 1.0$: SITA-standard: $y = 1.00 \pm 0.07*x - 1.6 \pm 0.5$.

Prea et al. AJO (2018)

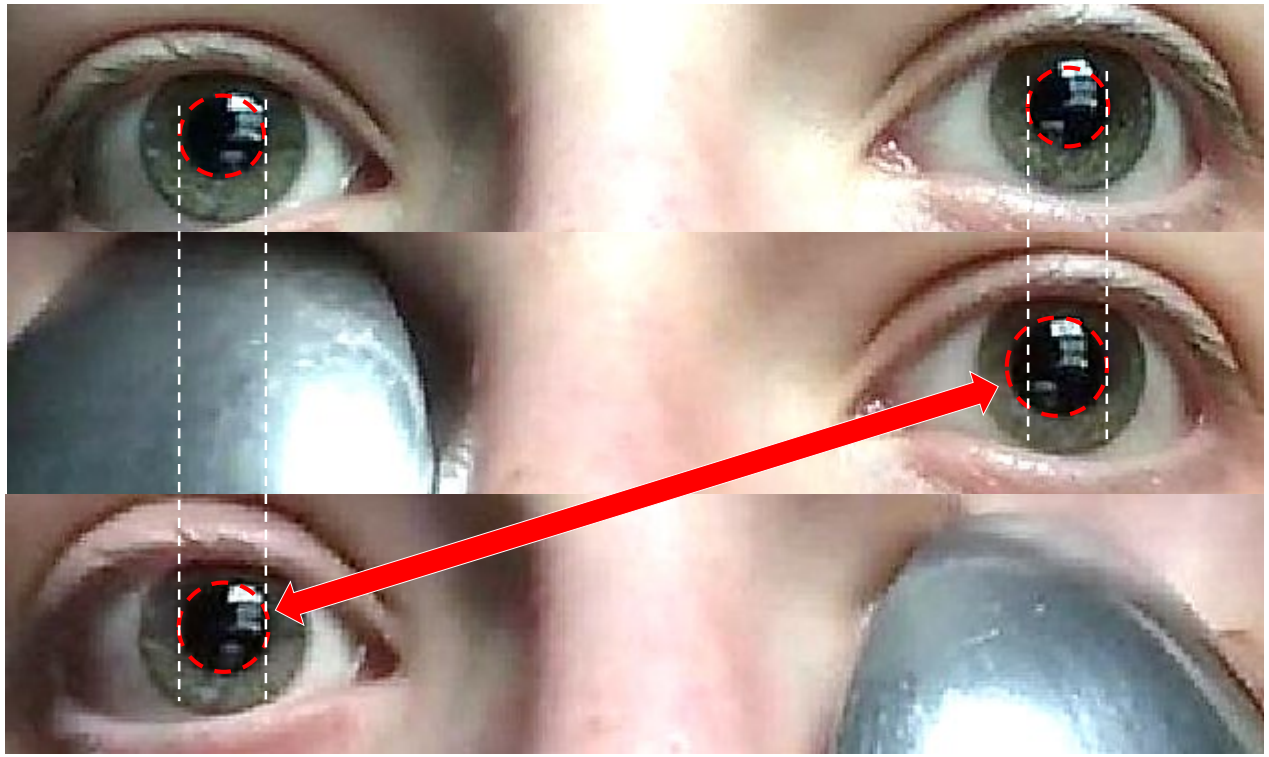

EFFERENT
VISION
TESTING

EFFERENT TESTING RECOMMENDATIONS

- Absent freely *available*, practical & validated apps for efferent testing: pupillary reflex, ocular position, or eye movements.

- RAPD can be detected in daylight if the other pupil is covered (dark).
- Difference = Kestenbaum Pupil Number (KPN)

RAPD Testing in Telemedicine



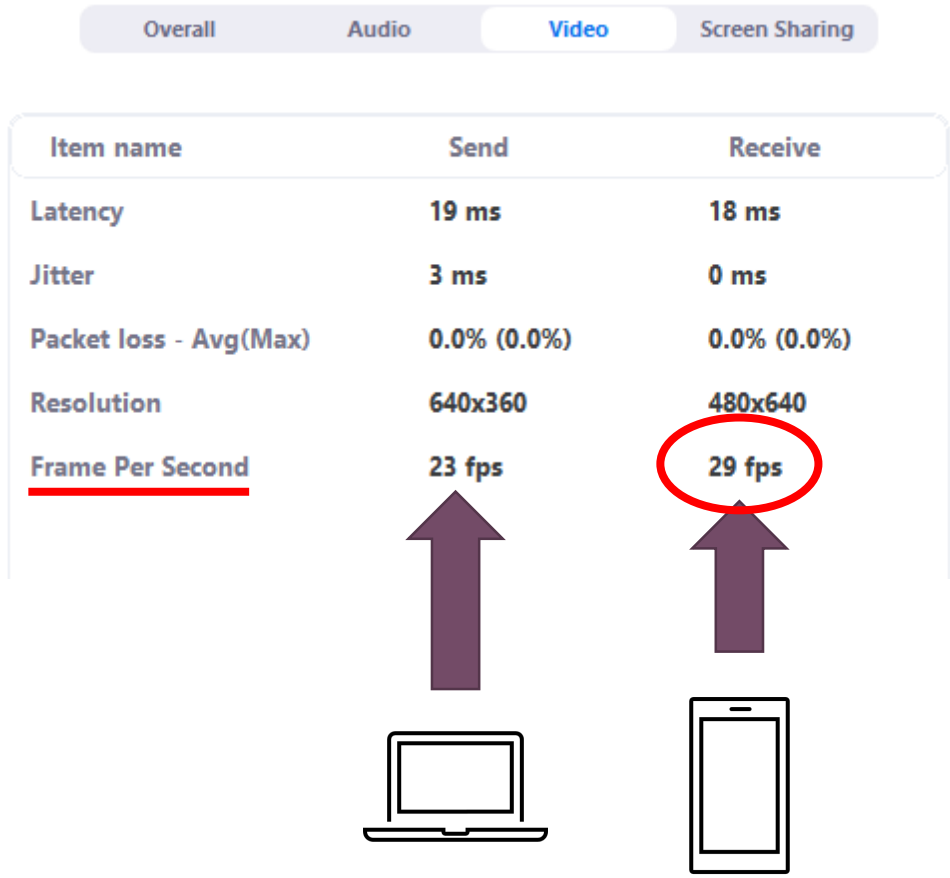
25 yo with Left Optic Atrophy

Sun LD, Odel JG.
J Neuroophthalmol. 2020 Sep;40(3):442.

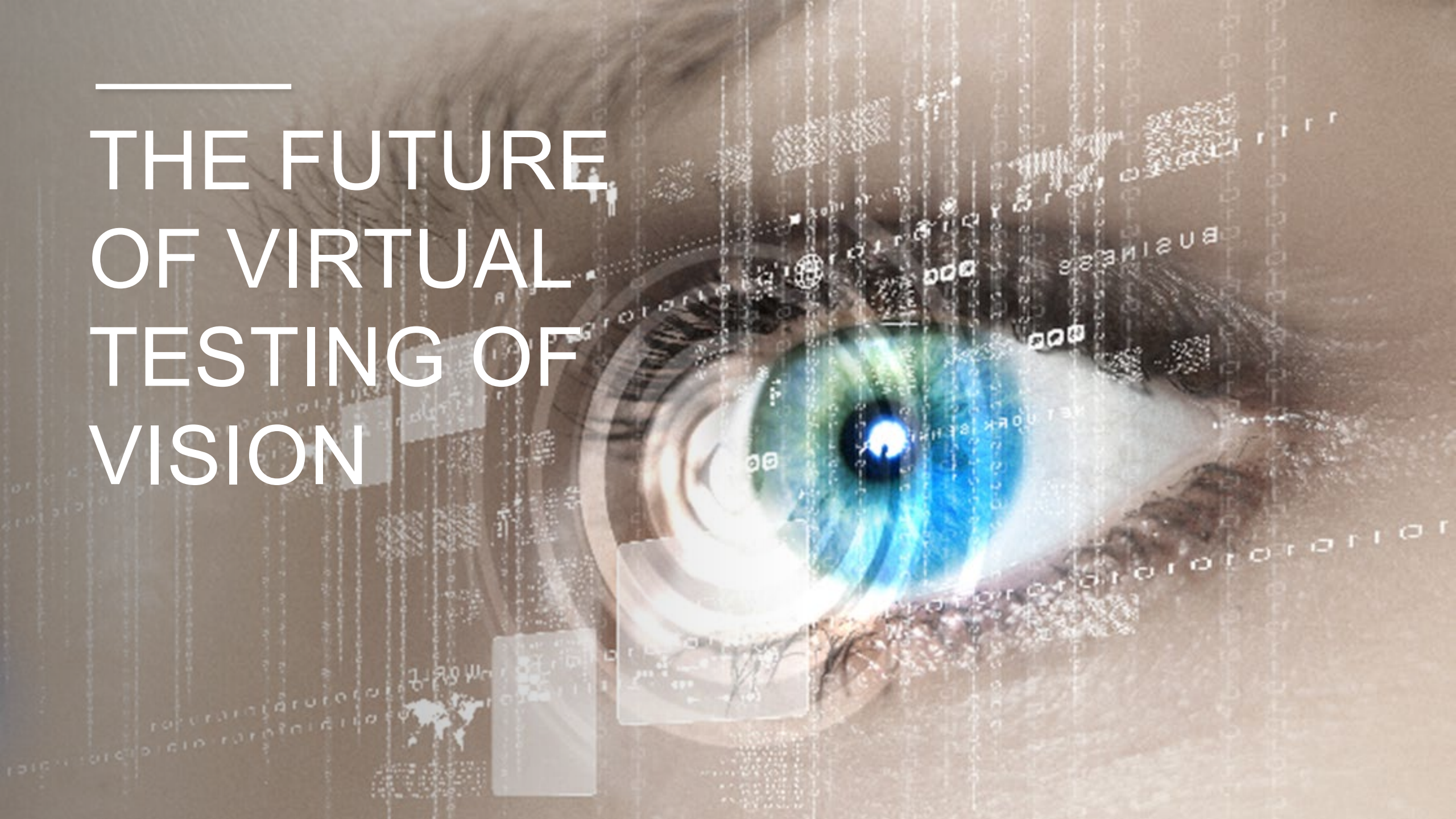
EFFERENT EXAM TIPS

- Warning: Teleconference apps are not designed for evaluating quick eye movements: 30 frames per second (fps) max!
- Tip: Improve lighting. Patients should use their higher quality smart phone cameras instead of laptop or desktop webcams.
- Slow eye movements can be seen: static binocular gaze misalignment, gaze palsies, convergence or divergence insufficiencies.
- Eye Movements that ***may*** require faster video: saccadic slowing, INOs, dysmetria, intrusions, nystagmus, saccadic pursuit and abnormal VOR suppression.

Zoom Control Panel - Statistics



THE FUTURE OF VIRTUAL TESTING OF VISION



VIRTUAL FIELDS HEAD MOUNTED DEVICES

ORIGINAL STUDY

Preliminary Report on a Novel Virtual Reality Perimeter Compared With Standard Automated Perimetry

Reza Razeghinejad, MD, Alberto Gonzalez-Garcia, MD,† Jonathan S. Myers, MD,* and L. Jay Katz, MD**

Precis: The VisuALL head-mounted perimetry in normal subjects and glaucoma patients had a moderate to strong correlation with the Humphrey Field Analyzer (HFA).

Purpose: Visual field testing has a vital role in diagnosing and managing glaucoma. The current clinical practice relies on large, table-based testing units. This study investigated the performance of a novel virtual reality head-mounted visual perimetry device (VisuALL), in normal and glaucoma patients.

Methods: This prospective observational study was conducted on 50 eyes of 25 healthy subjects (normal group) and 52 eyes of 26 patients with a controlled mild or moderate stage of glaucoma (glaucoma group). All participants had visual field testing with VisuALL and the HFA (24-2, Swedish Interactive Threshold Algorithm). The mean sensitivity of the whole visual field and each quadrant were compared between both machines and the receiver operating characteristic was used to compare the diagnostic abilities and the Bland-Altman plot to evaluate the agreement of the 2 perimeters.

Results: The global mean sensitivity of the Visu*ALL* and the HFA correlated significantly in both normal ($r = 0.5$, $P = 0.001$) and glaucoma ($r = 0.8$, $P < 0.001$) groups. The mean sensitivity of all quadrants also correlated significantly in both groups. The Visu*ALL* mean sensitivity had a greater (0.98) receiver operating characteristic curve than HFA (0.93) mean sensitivity ($P = 0.06$) in discriminating normal versus glaucoma.

Conclusion: There was an excellent correlation between the VisuALL and the Standard Automated Perimetry in normal and glaucoma patients and VisuALL showing high diagnostic performance.

commonly used clinical tool for characterizing the level of visual loss of glaucoma and neurological diseases and for detecting the disease progression.[1]

The SAP requires maintenance of constant fixation for several minutes and conscious decision making in identification of near the threshold level stimuli.[2,3] In addition, it has a number of disadvantages including being stressful for debilitated, claustrophobic, ill, or elderly patients to keep their heads still in the perimeter bowl during the test. Patients with musculoskeletal problems and admitted patients in the hospital that are not able to position their head in the proper position for visual field testing may have unreliable, artifact laden results or be unable to take the test.

Several devices have been developed since the advent of the HFA and the Octopus perimeters, in an effort to improve the detection of visual field defects and make the test easier for patients.[4–6] Examples include the use of laptops and iPads.[7–9] These modalities bring portability, but lack of fixation monitoring methods and hardware standardization have been the limiting factors in their widespread use. In addition, specificity and sensitivity studies have been mixed.[7,8,10,11] The majority of these devices are composed of a head-mounted device (HMD) controlled by a laptop or a tablet.[8,12] The size and cost of current tabletop perimeters limit their use in screening efforts as well as clinical care in remote and rural settings. HMD perimeters may allow in-office, remote, and home visual field testing owing to their lower cost and portability and could promote a change in

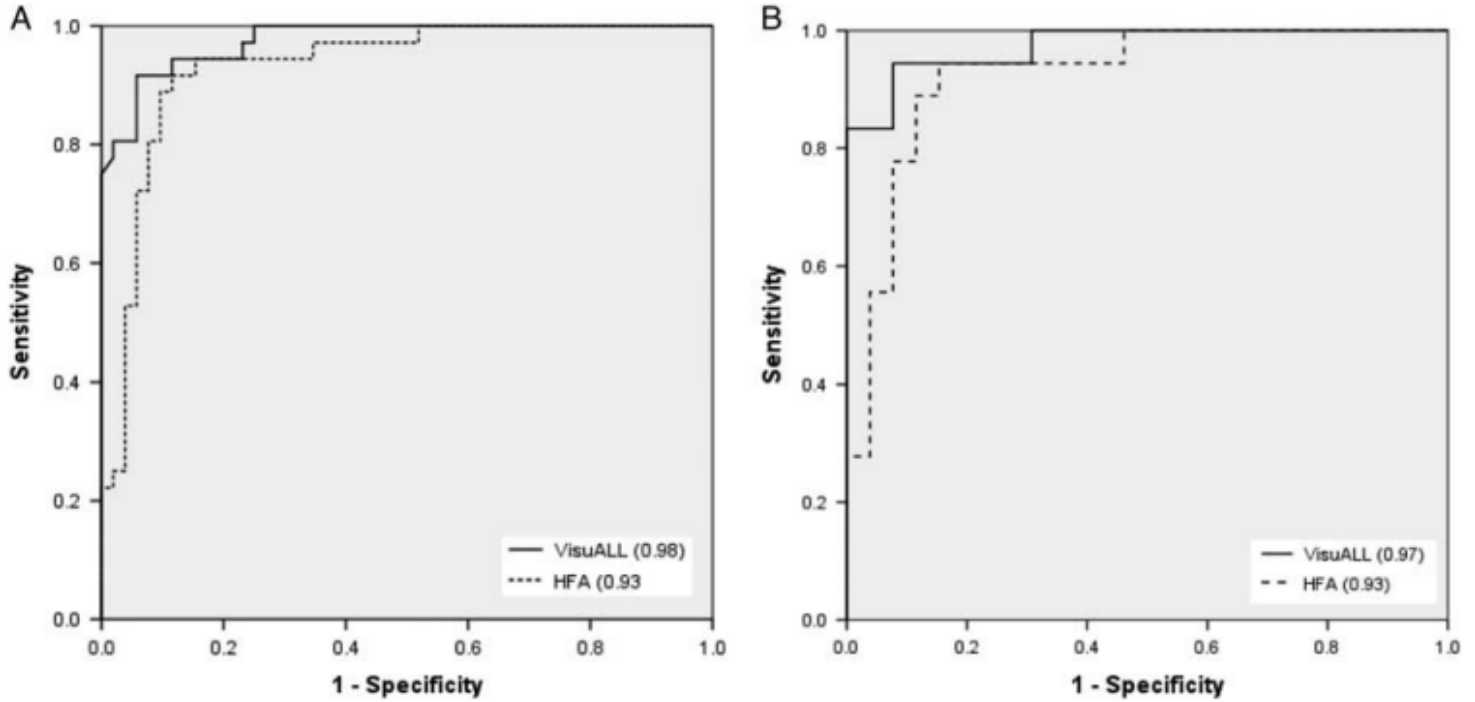


FIGURE 3. Receiver operating characteristic curve of the mean sensitivity of VisuALL and Humphrey Visual Field in both (A) and right eyes (B). HFA indicates Humphrey Field Analyzer.

VisuALL ROC = 0.98

HFA ROC=0.93

ORIGINAL ARTICLE

Artificial Intelligence to Detect Papilledema from Ocular Fundus Photographs

Dan Milea, M.D., Ph.D., Raymond P. Najjar, Ph.D., Zhubo Jiang, M.Sc., Daniel Ting, M.D., Ph.D., Caroline Vasseneix, M.D., Xinxing Xu, Ph.D., Masoud Aghsaei Fard, M.D., Pedro Fonseca, M.D., Kavin Vanikieti, M.D., Wolf A. Lagrèze, M.D., Chiara La Morgia, M.D., Ph.D., Carol Y. Cheung, Ph.D., et al., for the BONSAI Group*

April 30, 2020
N Engl J Med 2020; 382:1687-1695
DOI: 10.1056/NEJMoa1917130
Chinese Translation 中文翻译

39 References 82 Citing Articles

Abstract

BACKGROUND

Nonophthalmologist physicians do not confidently perform direct ophthalmoscopy. The use of artificial intelligence to detect papilledema and other optic-disk abnormalities from fundus photographs has not been well studied.

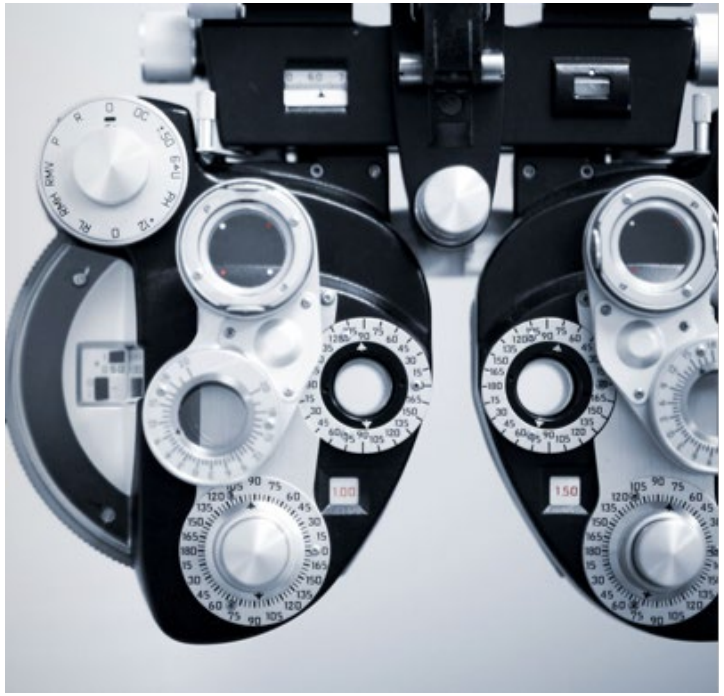
Related Articles

EDITORIAL APR 30, 2020

AI for the Eye — Automated Assistance for Clinician Screening for Papilledema

I. Kohane

TAKEAWAYS



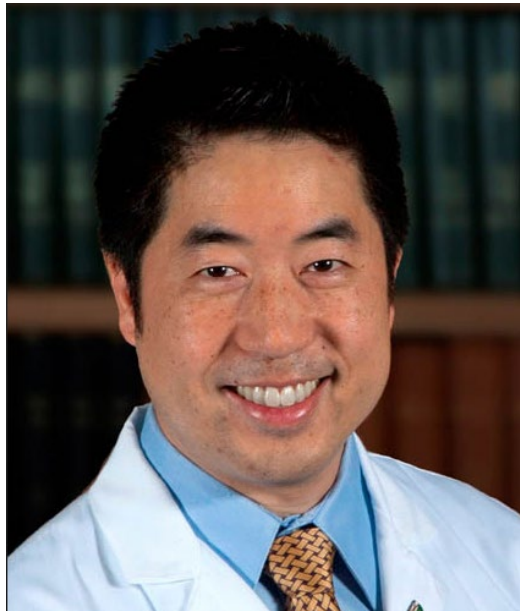
- **Eye Handbook is validated**, free/easy to use, but slightly **over-estimates visual,** may lead to false negative test results.
- **Kay iSight,** low error rate, easy to use, initially free, but test letters randomize with each use
- **MRF** Visual Fields is validated, now a cloud-based **web application** (Eyesimplify.com, M&S Tech).

  Use with ***reliable*** **patients and iPad browsers**.
- Teleconference video quality is lacking to assess fast eye movements: improve with **bright diffuse lighting**, **cell phone cameras** (not laptop/webcam)

WHAT IS STILL NEEDED?

- Validated, practical, easy to use and affordable/free visual testing applications for patients to use from home
- No existing studies that compare vision app vs app in telehealth environment
- Home based VR Goggles interesting alternative to tablet-based VF testing (affordability?)
- Fast paced upgrades in visual testing tech requires flexible infrastructure in disability evaluation to accommodate rapid changes

ACKNOWLEDGEMENTS



- **Linus Sun**

- **Indiana University**
- Devin Mackay
- Kevin Lai

- **Cornell**
- Marc Dinkin
- Cristiano Oliveira

- **UCSF**
- Nailyn Rasool
- Christopher Johnson

NYU

Neil Busis

Janet Rucker

Laura Balcer

Steve Galetta

Scott Grossman

Columbia

Jackson Scharf

Jeffrey G. Odel

Stanford

Heather Moss

RESOURCES

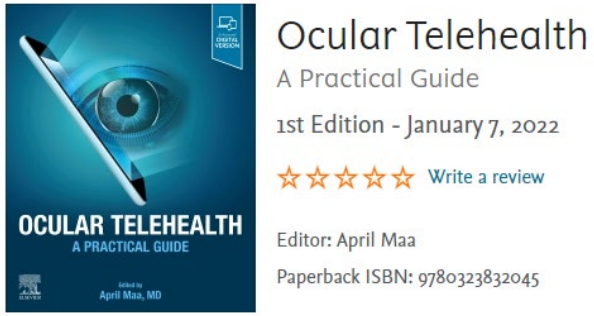
- Lai KE, Ko MW, Rucker JC, Odel JG, Sun LD, Winges KM, Ghosh A, Bindiganavile SH, Bhat N, Wendt SP, Scharf JM, Dinkin MJ, Rasool N, Galetta SL, Lee AG. Tele-Neuro-Ophthalmology During the Age of COVID-19. J Neuroophthalmol. 2020 Sep;40(3):292-304. doi: 10.1097/WNO.0000000000001024. PMID: 32604249; PMCID: PMC7418186.
- Mena-Guevara KJ, Piñero DP, de Fez D. Validation of Digital Applications for Evaluation of Visual Parameters: A Narrative Review. Vision (Basel). 2021 Nov 24;5(4):58. doi: 10.3390/vision5040058. PMID: 34842847; PMCID: PMC8628957.
- Steren BJ, Young B, Chow J. Visual Acuity Testing for Telehealth Using Mobile Applications. JAMA Ophthalmol. 2021 Mar 1;139(3):344-347. doi: 10.1001/jamaophthalmol.2020.6177. PMID: 33443550; PMCID: PMC7809609

- American Academy of Ophthalmology Home Vision Eye Charts for Children and Adults

https://www.aao.org/eye-health/tips-prevention/home-eye-test-children-adults

- Ocular Telehealth: A Practical Guide (2022)

https://www.elsevier.com/books/ocular-telehealth/maa/978-0-323-83204-5



RESOURCES: PREPARING PATIENTS FOR TESTING IN TELEMEDICINE

- Drs. Shannon Beres & Heather Moss
- Byers Eye Institute/Stanford
  - YouTube videos to provide guidance on neuro-ophthalmic testing of adult and pediatric patients.

- Dr. Dan Gold's Collection at NOVEL
- Johns Hopkins
  - "Telemedicine Ocular Motor Examination"
  - https://novel.utah.edu/Gold/