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Smartphone-Based Visual Acuity Measurement for Screening and Clinical Assessment

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Abstract

IMPORTANCE—Visual acuity is the most frequently performed measure of visual function in clinical practice and most people worldwide living with visual impairment are living in low- and middle-income countries.

OBJECTIVE—To design and validate a smartphone-based visual acuity test that is not dependent on familiarity with symbols or letters commonly used in the English language.

DESIGN, SETTING, AND PARTICIPANTS—Validation study conducted from December 11, 2013, to March 4, 2014, comparing results from smartphone-based Peek Acuity to Snellen acuity (clinical normal) charts and the Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR chart (reference standard). This study was nested within the 6-year follow-up of the Nakuru Eye Disease Cohort in central Kenya and included 300 adults aged 55 years and older recruited consecutively.

MAIN OUTCOMES AND MEASURES—Outcome measures were monocular logMAR visual acuity scores for each test: ETDRS chart logMAR, Snellen acuity, and Peek Acuity. Peek Acuity was compared, in terms of test-retest variability and measurement time, with the Snellen acuity and ETDRS logMAR charts in participants' homes and temporary clinic settings in rural Kenya in 2013 and 2014.

RESULTS—The 95%CI limits for test-retest variability of smartphone acuity data were ±0.029 logMAR. The mean differences between the smartphone-based test and the ETDRS chart and the smartphone-based test and Snellen acuity data were 0.07 (95%CI, 0.05–0.09) and 0.08 (95%CI, 0.06–0.10) logMAR, respectively, indicating that smartphone-based test acuities agreed well with those of the ETDRS and Snellen charts. The agreement of Peek Acuity and the ETDRS chart was greater than the Snellen chart with the ETDRS chart (95%CI, 0.05–0.10; $P = .08$). The local Kenyan community health care workers readily accepted the Peek Acuity smartphone test; it

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Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Brady reported having a patent pending for a disposable retina and anterior segment imaging system for use in contaminated and resource-poor settings. Dr Eghrari reported having a patent pending for Ebola-Scope, a smartphone-based retinal imaging device. No other disclosures were reported.

required minimal training and took no longer than the Snellen test (77 seconds vs 82 seconds; 95%CI, 71–84 seconds vs 73–91 seconds, respectively; $P = .13$).

CONCLUSIONS AND RELEVANCE—The study demonstrated that the Peek Acuity smartphone test is capable of accurate and repeatable acuity measurements consistent with published data on the test-retest variability of acuities measured using 5-letter-per-line retroilluminated logMAR charts.

Visual acuity is perhaps the most well-known and most important measure of visual function. The concepts of “20/20” and “the big E” are familiar to patients and physicians in all fields of medicine. Visual acuity can be measured rapidly and inexpensively, with low-cost charts available commercially, online for printing, and increasingly for mobile devices.

Clinically, visual acuity is considered one of the vital signs of the eye and is measured at a predetermined distance, often using a Snellen chart. Developed in the 1860s, this chart has several design flaws, such as nongeometric progression of letter size and variable number of letters used per line (eg, “E” at the top of the chart and ≥5 letters on the 20/20 line). When measuring acuity in epidemiologic surveys or as an outcome in clinical research, the Snellen chart is insufficiently standardized, and other charts have been developed to address these deficiencies.[1] The most well known of these is the retroilluminated logMAR (logarithm of the minimum angle of resolution) chart that was used in the Early Treatment Diabetic Retinopathy Study (ETDRS) and has since become the standard method of measuring visual acuity in prospective clinical research.[2]

Each line of the ETDRS chart has 5 letters (“optotypes”) and is a fixed proportion larger (1.2589× or 0.1 log) than the line below. Despite any viewer’s starting acuity, a worsening of 3 lines on the chart corresponds to a doubling of the visual angle, making the measure more amenable to rigorous analyses.[1] Because the EDTRS chart requires a 4-m examination room and a large retro-illumination system and can cost upwards of $1000,[3] the ETDRS chart has yet to be adopted widely for clinical use.

In the August 2015 issue of *JAMA Ophthalmology*, Bastawrous et al[4] described a novel smartphone-based technique for measuring distance visual acuity. The ETDRS-based app (the Peek Acuity app) was validated against Snellen charts and a clinic measurement using the ETDRS chart as part of an epidemiologic eye survey among adults in central Kenya. The app uses the smartphone platform, conferring an advantage over traditional logMAR acuity measurement. When grading is done within the app, the tester is blinded regarding the correct response. The new app uses only the letter “E” in 4 orientations. The examinee points in the direction of the arms of the E, and the tester records the answer by swiping across the screen in the same direction. This helps prevent subtle or subconscious clues to the examinee (eg, “Are you sure?” or a raised eyebrow to an incorrect response), and the examiner is not responsible for determining when the testing is completed or how the scoring is done. The app senses ambient light and automatically adjusts screen brightness. If the surroundings are too bright for accurate measurements, an alert is generated.

When comparing visual acuity testing using the app at the study participants’ homes with ETDRS acuity at a centralized clinic with 272 participants, Bastawrous et al[4] found that the

mean difference between the measurements was less than 1 line of vision. When comparing testing using the app in the clinic with ETDRS in the clinic, the mean difference was less than 3 letters. The authors were unable to perform ETDRS testing in a second scenario, which might have revealed the degree of test-retest variability (TRV) within their reference standard and have helped put the relatively low TRV of the app in context. In other studies, TRV of up to 2 lines has been reported with ETDRS testing.[2] The investigators found the use of their app took no longer than Snellen testing and concluded that the app was repeatable and consistent. The authors also highlighted the value added of using a smartphone platform beyond measurement of visual acuity, including connectivity and ability to associate global positioning system coordinates with clinical data.

A clinician or investigator interested in using this app to replace ETDRS testing must account for several practical considerations. First, individual handsets vary in size and resolution, requiring users to calculate and adapt appropriate distance between the examiner and patient, although it is possible this could become an automated feature within the app. Second, smartphones may be costly, particularly for models with the highest-quality screens. Indeed, the smartphone used in the study by Bastawrous et al[4] is currently sold for $100 despite its having been replaced by 3 subsequent iterations of the model. Moreover, the tumbling E version of the chart was not used in the ETDRS nor in the initial validation of the logMAR chart. Indeed “E” is not among the 10 optotypes used in the ETDRS chart.

The use of mobile phone technology for the delivery of health care is rapidly expanding. There are more than 100 vision test apps in the Google Play Store, but few, if any, have been robustly validated.[5,6] The medical community should not allow convenience and affinity for new technology to trump the responsibility to collect accurate clinical data. There could be adverse consequences of poor mobile health app performance, such as generating unreliable clinical data or displaying inappropriate information to patients.[7] Because of gaps in the regulatory framework, regulatory agencies have been circumvented by disclaimers against clinical use of the apps or app developers stating that the apps should be used for “entertainment only.” Yet it is often clear that the app designers target sophisticated clinical users. Moreover, the principles governing health care delivery and protecting patients should guide the development of these innovations.[8] The Principles for Digital Development are one set of guidelines that organize a set of best practices,[9]many of which appear to have been followed by this team. However, robust guidelines governing the design of clinical apps are still scant. Bastawrous et al[4] demonstrate, through the development of a tool with cross-cultural capabilities, the possibility of applying these tools in a robust and meaningful way to deliver value to patients wherever they may reside.

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