NETRA-G: Towards a Subjective Self-Refraction

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Abstract: We discuss NETRA-G's sphero-cylindrical self-refractions for teenagers. NETRA-G achieved accuracies of $.48D$ on sphere and $.30D$ on cylinder. Visual acuity was $20/20$ or better in 70% of all cases and $20/25$ or better for 90%.

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1. The Need for a Disruptive Technology

600 million [1] to 2.5 billion [2] people are in need for corrective eyewear. Most of them are unaware of their visual condition. Today, the majority of refractive assessment devices employ sophisticated engineering to precisely and objectively estimate optical aberrations while neglecting the benefits of user-centric designs and ubiquitous computing platforms, such as smartphones. Such level of sophistication requires 4-7 years of medical trainings, costly maintenance, sensitive optical calibration procedures and tight usage procedures which decrease its accessibility to the population. NETRA-G [3] is a low-cost refractive assessment tool that requires minimum training and no calibration. It couples the Schneier principle [4] with Spatially Resolved Refractometers [5] to create the dual of Shack-Hartmann techniques [6]: a smartphone's display captures user feedback to quantify the local displacement on the eye's naturally occurring wavefront. The device consists of a plastic-molded binocular housing (fixation system) with basis optic lenses, simple mechanical components (e.g. centration and alignment interfaces), and an Android application that operates on the Samsung Galaxy S4 smartphone. NETRA-G outputs interpupillary distance (IPD), spherical and cylindrical error, and axis of astigmatism. The subject simply looks through the binocular-like device and aligns red and green lines at various angles. By best-fitting the measurements from eight angles per eye, the application computes the patient's refractive error. The technology seeks to empower patients worldwide by offering a comprehensive self-refraction tool with uncompromising precision and affordability.

This report presents a side-by-side comparison with teenagers. Subjects undergo a Shack-Hartmann assessment (SH: Zeiss iProfiler Plus), open-field autorefraction (AR: Grand Seiko WR-5100K), NETRA-G Refraction, and Subjective Refraction (SR). The purpose of an ophthalmic refraction is to determine the combination of spherical and cylindrical lenses that optimize the subject's visual acuity (VA) when the eye is relaxed. Since all existing techniques are error prone, we avoid human and machine error on traditional side-by-side comparisons by measuring the VAs for all refractions using a logMar chart. Any given refraction on a subject is compared to the method that yields the best VA across all available techniques (henceforth Best VA method). If the VA is the same between any two methods, the method with the smallest spherical equivalent is chosen as the best refraction ("maximum plus" optometric protocol).

2. The Teenager Study

48 healthy eyes (mean $\pm$ SD age 14.67 ± 1.60 years) participated in this study. The subjects' spherical refractive error ranged from $-8.25D$ to $+3.50D$ and the maximum cylindrical error was $-3.00D$. The IPD was $61.12mm \pm 3.18mm$ and the best corrected VA was $20/20 \pm 1.15$ lines on a logMar chart (worst case was $20/25$). The average test time on NETRA-G was $6{:}14 \pm 2{:}55$ minutes. This group's overall behavior, attention span, and desire to participate were generally favorable towards NETRA-G. Several compared NETRA-G's experience to a fun interactive game.

The majority of the NETRA-G measurements yielded a VA within one line from the Best VA. NETRA-G achieved a VA of $20/20$ or better in more than 70% of the cases and 20/25 or better in almost 90% of them. The average absolute difference was .48D on sphere against SR. This is only $.19D$ more error than the difference between SH and SR ($.29D$). Nevertheless, NETRA-G exhibited a smaller error in cylindrical correction than SR when compared against SH ($\Delta.30D$ NE-SR compared to $\Delta.45D$ SH-SR). The axial measurements were similar as well ($7.32°$ SH-SR vs $11.00°$ NE-SR). The average absolute difference for the IPD measurements was $1.12 \pm 1.61mm$ with SH as a gold-standard.

Fig. 1 (bottom) shows a complete picture of the results by comparing the accuracy of each subject from the SH (points in green) and NETRA-G (points in red) against SR. Positive values on the y-axis represent a worse VA (obtained from the SH and/or NETRA-G) than that yielded from SR. Negative values state that the devices yielded a better VA than test results obtained by optometrists. The x-axis displays the difference in refractive power in terms of vector dioptric distance (VDD). Positive values on the x-axis indicate that SR was stronger (more minus) than the other

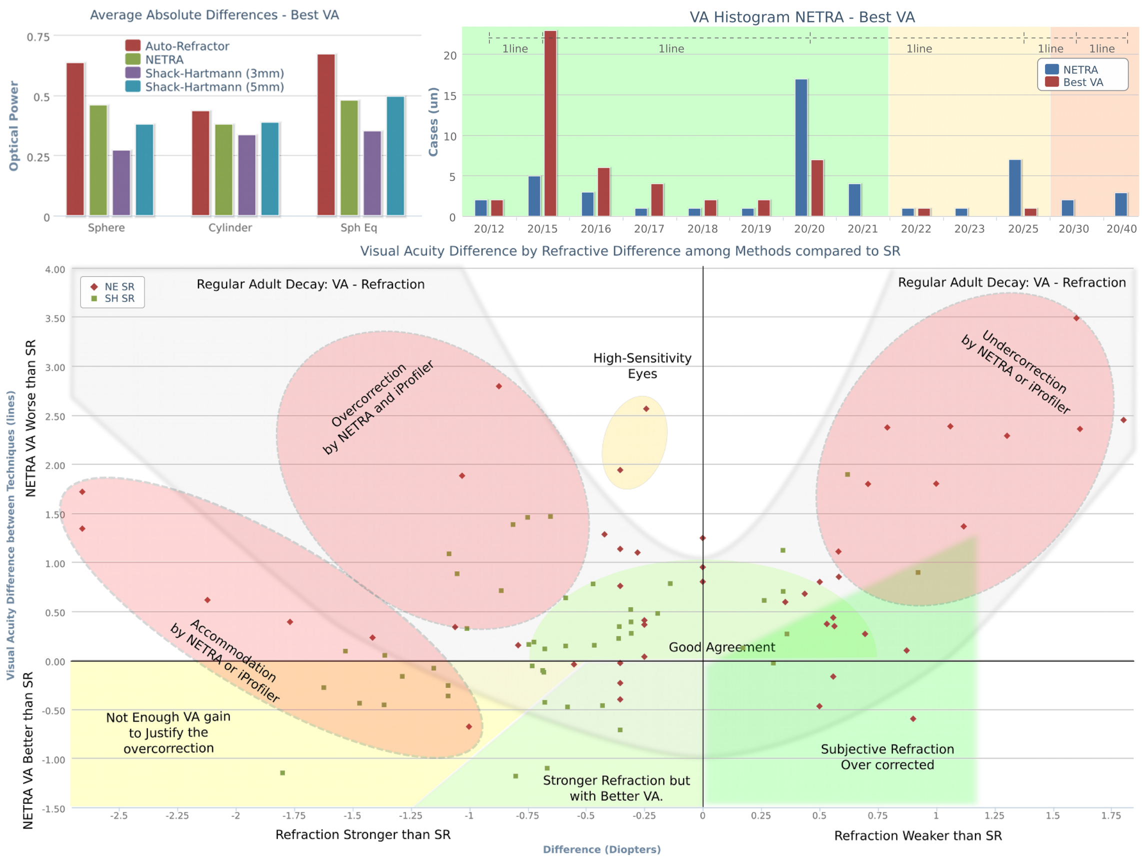

Fig. 1. (top-left) Average absolute differences against the Best VA method. (top-right) Histogram of VA between NETRA-G and Best VA. (bottom) Correlation between changes in VA and changes in vector dioptric distance (VDD) for NETRA-G and the SH compared to SR as gold standard.

methods. In other words, either the SH or NETRA-G may have under-corrected or SR may have over-corrected. The gray section illustrates the expected decay of VA given the respective changes of refractive error.

NETRA-G presented bigger differences when compared to SR. The SH presented a systematic bias, overcorrecting by $.5D$ against SR. The green sections highlight where NETRA-G and SH performed better or as good as the SR. The red sections show significant under and over-correction by both methods. While both instruments experienced the same quantity of accommodation occurrences, those instances impacting the NETRA-G were generally more severe (i.e. stronger refractions). The green section labeled ”Subjective Refraction Overcorrected” shows that NETRA-G and the SH resulted in a weaker and thus better refraction than SR while keeping the same or better VA.

3. Conclusion

The synthesis of this study demonstrates that NETRA-G is already a viable refraction solution for high school students (i.e. appropriate for ages 14-18 years). Moreover, NETRA-G’s evolution towards a self-test solution has significantly improved the user experience and accommodation control without sacrificing accuracy.

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