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Comparison of the automated First 3D™ vision screener to a manual driver vision screening method in Gauteng (South Africa)

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Authors:
Thokozile I. Metsing[1]
Nabeela Hasrod[1]

Affiliations:
[1]Department of Optometry, Faculty of Health Sciences, University of Johannesburg, Johannesburg, South Africa

Corresponding author:
Thokozile Metsing,
ingridm@uj.ac.za

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Background: The automated (First 3D™) vision screener developed for the South African licensing department was designed to address the limitations in the current driver vision screening tests.

Aim: To compare distance visual acuities (VAs) and visual fields (VFs) using the First 3D™ vision screener with the manual method, both with and without the use of spectacles.

Setting: Optometry clinic at the University of Johannesburg.

Methods: Visual acuities and temporal VFs of 98 participants (18–68 years) were measured using both the automated First 3D™ and manual methods (Snellen Tumbling E's and Novice™ sphere). *T*-test and correlation coefficients assessed associations and the direction of linear relationships between the two screeners.

Results: A moderate, positive and statistically significant correlation was found between the manual and automated VA assessments for the right oculus dexter (OD) and left eyes oculus sinister (OS), with $r = 0.44$, $P < 0.001$ and $r = 0.54$, $P < 0.001$, respectively. A significant positive correlation was observed for OD VF measurements ($r = 0.365$, $P < 0.001$) but not for the OS ($r = 0.028$, $P = 0.788$).

Conclusion: Although both methods showed similar VA trends, agreement between them was weak, indicating that the two methods should not be used interchangeably for individual VA assessments. No significant differences were found between manual and automated VF testing methods; however, factors such as test sensitivity, examiner judgement, eye dominance, calibration and procedural variation warrant cautious interpretation.

Contribution: Findings support improvements in driver vision screening and policy development for standardised vision testing in licensing systems.

Keywords: visual acuity; visual field; novissphere; drivers; peripheral vision.

Introduction

Vision is very important for safe driving because it provides most of the information needed to navigate and respond to road hazards. Screening visual functions, including visual acuity (VA), visual fields(VFs), depth perception and contrast sensitivity, contribute towards the identification of drivers who may be at increased risk of accidents.[1] In addition, routine vision screenings enable early detection of eye conditions, ensuring timely interventions, maintaining driving eligibility and enhancing overall road safety.[2,3]

Visual acuity determines the quality and range of the person's vision, crucial for driving.[4] Reduced VAs affects the ability to judge space and distance between objects. Peripheral vision, contributing to a total field of perception, is also affected by reduced VAs. When stationary, a person has a 180° horizontal field of vision and a 130° vertical field of vision. Good binocular depth perception is important in determining how fast an object is moving, as it is also used by pedestrians when crossing roads or when drivers move to the opposite sides of the road to overtake.[5] The implications of reduced VAs and VFs in driving are far-reaching, as these two aspects of vision are essential for maintaining safety on the roads.[3,5] Drivers with compromised VAs or VFs may experience difficulty in perceiving their environment, which can lead to potentially hazardous situations.[6] Recognition of traffic signals and interpreting road signs are tasks that heavily rely on the driver's VA.[7] Furthermore, drivers must be able to discern the position and movement of other vehicles, pedestrians and potential obstacles.[8] Inadequate VA can result in slower reaction times and an increased likelihood

of accidents resulting from drivers struggling to make appropriate decisions promptly.[9,10]

Visual fields are crucial for maintaining a comprehensive understanding of the driving environment.[8] The legal requirement for South African drivers is a minimum VF of 70° temporal and a minimum total horizontal VF of at least 115°. This allows drivers to perceive objects and events occurring in their peripheral vision without needing to shift their focus away from the road ahead.[9] This ability is especially important when making lane changes, merging onto highways or navigating through busy intersections. Drivers with restricted VFs may fail to notice potential hazards that are situated outside their limited range of vision, which can lead to dangerous situations and increased risk of accidents.[10] Considering the importance of VAs and VFs in driving safety, the licensing authorities must establish stringent standards for vision assessment.[11] Comprehensive vision testing should be a mandatory component of the driver's licensing process, and individuals with visual impairments should be encouraged to seek appropriate treatment to improve their visual functions.[10]

Regular eye examinations and timely interventions can help address vision-related issues before adversely impacting an individual's driving abilities.[11] Hence, the purpose of this study was to carry out a comparative study aimed at comparing the uncorrected and/or corrected distance VAs through spectacles or CLs and VFs obtained using the First 3D™ vision screener with that of a standard vision screening method conducted by clinicians in the optometric test room. Challenges such as equipment maintenance and operational reliability remain; ongoing advancements and applications in various sectors suggest a growing commitment to integrating technology for improved service delivery.[12] Therefore, the requirement for improved and reliable vision screening machines in the driver's licensing departments is necessary to ensure safety on the roads. Furthermore, the implementation of automated eye testing machines at Driver's Licence Testing Centres (DLTCs) in Gauteng was found to contribute to increased failure rates among applicants.[13,14,15]

The machines used to evaluate vision, while designed to enhance efficiency, were found to be more conflicting than their manual counterparts, performed by qualified optometrists. Thus, some of the applicants who previously passed manual tests were found to fail the automated assessments.[16] Factors contributing to these failures included slight head movements during testing, misalignment of letters in the machine, improper positioning and instructions from the examining officer, insufficient head space for positioning the patient's face wearing spectacles to look through the eyepieces and perhaps deteriorating vision that was not previously detected.[17,18] The automated First 3D™ vision screener was created to improve the accuracy and efficiency of vision screening, especially for individuals who may not be able to articulate or express difficulties with their vision.[7,8] The modified vision screener (First 3D™), a newly developed electronic instrument based on existing models, was used in this study. The First 3D™ was presented to an academic department for validation, and this process required the instrument to be used for research and compared to the manual methods of vision screening, including assessments of VAs using the Snellen charts at 6 metres and the Novis Sphere to assess VFs.[10]

The Novis Sphere was used in this study to assess VFs to identify and diagnose peripheral VF defects caused by glaucoma, retinal diseases and neurological disorders. Research directly evaluating the Novis Sphere remains limited; nevertheless, the device was endorsed by the Technicon of Witwatersrand (TWR), which subsequently merged with the Rand Afrikaanse Universiteit (RAU) to form the University of Johannesburg. This endorsement underscores the device's importance in optometry and its potential use in clinical applicability, suggesting its potential in research credibility, scientific validation and clinical acceptance, leading to its recognition scientifically and its professional validation.

Regular eye examinations and timely interventions can help address vision-related issues before adversely impacting an individual's driving abilities.[10] The purpose of this study was to conduct a comparative analysis of visual function assessments using automated and manual tests. The assessments included uncorrected visual acuity and visual acuity corrected with spectacles or contact lenses. Visual fields were also evaluated by comparing the automated first 3D method with the Novis Sphere, which is regarded as a manual test.

Research methods and design

This study was cross-sectional with a quantitative approach. One hundred participants (n = 100) aged between 18 and 68 years, women and men, and from all ethnicities were invited to participate in the study. No predetermined ocular or health conditions were required for the study. Monocular distance VAs were measured and recorded at 6 m using the Tumbling E Chart. If the participants were wearing spectacles or contact lenses for distance vision, their VAs were measured through correcting devices. In addition to the manual methods, the VF assessments were conducted using the Novis Sphere. The visual skills were evaluated and recorded using the First 3D™ visual screener instrument. The collected data from the two methods of vision screenings were then compared and analysed.

Procedure

Data were collected from participants at the Optometry clinic at the University of Johannesburg. Participation was voluntary, and written informed consent was obtained from each participant. The data collection in this study adhered to the tenets of the Declaration of Helsinki and was approved by the University Research Ethics Committee (REC-1789-2022). An information letter was provided to all potential participants, and a consent form was completed and signed by eligible participants. A basic questionnaire was used to

obtain the necessary information from each participant for the study.

Data were collected by six student researchers, blinded to the other data collection procedures. Two researchers measured VAs manually using the Tumbling E Chart in the room with illumination of 300 lux – 400 lux, the other two used the Novis Sphere to evaluate VFs and the other two used the automated First 3D™ machine to evaluate the VAs and VFs. Habitual VAs of each participant were measured monocularly using the Tumbling E optotypes displayed on an electronic self-illuminating digital screen at six meters in a brightly lit room of 350 lux. Participants wearing spectacles had their VAs measured through them, and those not wearing spectacles had their uncompensated habitual VAs measured. The Snellen chart optotypes the participants were to identify were displayed on an electronic self-illuminating digital screen six meters away from where the participant was sitting. Those wearing spectacles had their VAs recorded through them, and those not wearing spectacles had their VAs measured without them. All VA measurements were captured in Snellen notation and then converted to decimal notation. The measurements were capped at 1.00 (6/6;20/20) and 0.33 (6/18;20/60) in decimal notation because the automated vision screener VAs were limited to 6/6. Therefore, the maximum value was 1.00, and the minimum was 0.33. However, the automated screener did not have a 6/7.5 (0.8) line compared to the Snellen chart.

The Novis Sphere was used to assess VFs monocularly by presenting visual stimuli at various points in the peripheral field and measuring the patient's ability to detect them. During the assessment of the VFs using the Novis Sphere, patients were instructed to fixate on a central point through the central hole of the sphere. A light target was then introduced from the periphery and presented both nasally and temporally, in the eight positions corresponding to angles of 0°, 45°, 90° and 180°. Patients were then requested to indicate when they detected the light at these positions without moving their eyes. To minimise variability, manual measurement criteria, including objective documentation, consistent application, proper patient positioning, fixation monitoring, response recording, subjective interpretation, response reliability, and patient engagement, were standardised and carefully documented.

The second part of data collection involved participants being tested with the First 3D™ machine, designed to automatically measure VAs and VFs. The targets displayed by this machine displayed a series of Tumbling E optotypes at different VA levels, similar to the digital VA chart used for manual measurements. Participants were instructed to show by moving a joystick in the direction the Tumbling E was pointing. Visual field measurements were tested by a single light-emitting diode (LED) flash at angles 55°, 65°, 75°, 80° and 85° in the temporal fields of each eye, justified by expert consensus. The machine automatically measured and recorded the maximum measurements of the VFs. The VA and VF thresholds required to qualify for a driver's licence were pre-programmed into the machine. These include a minimum VA of 6/12 (0.5) in each eye or 6/9 (0.7) in the better eye if the individual is blind in one eye, with or without refractive correction.

Based on the preset criteria, the machine was capable of classifying participants as either passing or failing the driver's licence eye test. The researchers used the same criteria for manual measurements to maintain consistency. The collected data were analysed using Excel software, employing descriptive statistics, single-factor Analysis of Variance (ANOVA), correlation coefficients and scatterplots. These methods were chosen to provide a comprehensive comparison between manual and automated measurements of VAs and VFs. Agreement between the quantitative results of the manual and automated methods was assessed using the Bland–Altman statistical methods to determine the estimates of the mean difference and limits of agreement (LoA) between the two measurements of VAs using the manual and automated methods.[19,20]

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of Johannesburg, Faculty of Health Sciences Research Ethics Committee on 27 October 2022. The ethics approval number is REC-1789-2022.

Results

Of the 100 participants invited, 97 reported their age, yielding a mean of 34.30 ± 11.78 years. The male participants were in the majority (57%, n = 55), and 43% (n = 42) were female participants. Although participants' occupations varied (for example, students, office workers, managers) and they had different ethnic backgrounds, neither job type nor ethnicity was included in the analysis, as the focus of the study was to compare the outcomes of manual and automated vision screening methods rather than to examine occupational differences.

Descriptive data for visual acuities measured using the manual and automated First 3D™

Out of the 100 participants, VA measurements using the automated First 3D™ device could not be obtained from two participants: in one case, measurements were not possible for either eye, while in the other case, only the left eye could not be assessed. In contrast, VA measurements using the Snellen chart were successfully recorded for all participants. The mean VAs measured using the automated First 3D™ and Snellen for OD were found to be 0.83 ± 0.23 and 0.94 ± 0.15, respectively, indicating better VAs closer to 20/20 (1.00) using the Snellen Chart and reduced VAs of approximately 20/25 (0.87) measured using the automated test. Similarly, the VAs measured using the automated First 3D™ for OS were found to be (0.86 ± 0.23), and those using the Snellen chart were 0.94 ± 0.15. The standard error for both the automated and the Snellen charts was found to be similar for OD and OS. The data distribution of the Snellen was found to have a higher negative skewness compared to that of the automated VAs for both OD and OS, thus

indicating a significant concentration of values on the higher end of 6/6 (1.00) VAs. The automated First 3D™ VA confidence level was found to be 0.05 for both OD and OS and for Snellen Acuities was 0.03, respectively, thus indicating low confidence using the Snellen chart, with only a 3% chance that the VA intervals contain the true parameters. The data distribution of the manual VAs was found to have a higher negative skewness compared to that of the automated VAs for both VAs for OD and OS, thus indicating a significant concentration of values around 1.00 (6/6) (Table 1).

A statistically significant (P = 0.001) relationship was found between the automated and manual VAs of the OD and OS, with a positive Pearson correlation coefficients of 0.44 and 0.54, respectively, thus showing a moderate positive relationship between the VAs measured for OS using the Snellen Chart and the automated test, meaning that the variables are more consistently aligned with each other in the same direction (Figure 1 and Figure 2).

Comparison of visual fields measured using the Novis Sphere and First 3D™

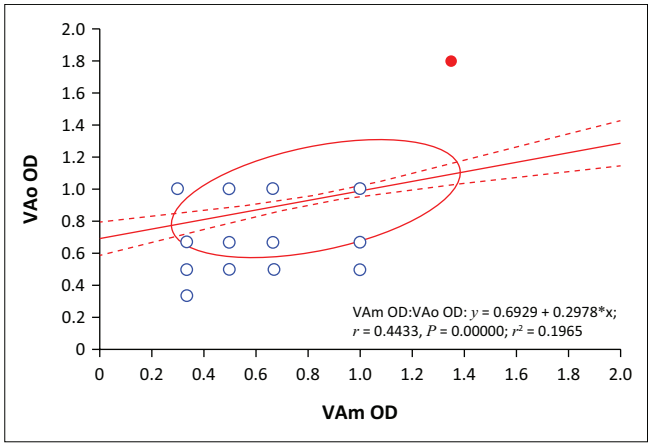
The mean VFs measured using the automated First 3D™ and Novis Sphere for OD were found to be 84.12 ± 3.15 and 82.29 ± 6.99, respectively. Visual field evaluations for OS were found to be 83.92 ± 3.97 and 82.92 ± 5.59, automated and manual, respectively. The standard deviations (s.d.) for the VFs measured using the manual method (Novis Sphere) were found to be high, indicating a wide spread of data from the mean compared to those measured using the automated method. Similarly, the standard error for the manual VF fields was found to indicate a high variability of the data collected using the Novis Sphere and a less reliable estimate. The sample variance between the two methods of Novis Sphere (OD:48.92 & OS:31.29), higher than that of the automated (9.90/15.74) measured VF, was found to be incomparable. The confidence level for the manual VF measurements for both OD (1.41) and OS (1.13) was found to be higher compared to those of the First 3D™, thus indicating less precision (Table 2).

A statistically significant (P = 0.02) relationship was found between the automated and manual VFs of OD, with a positive correlation coefficient of 0.36. No statistically significant relationship (P = 0.15) was found with the OS for the automated and manual VFs, with weak positive correlation coefficients of 0.03.

TABLE 1: Descriptive data for the visual acuities measured using the automated First 3D™ and Snellen chart.

Descriptives	1ST 3D™ OD	1ST 3D™ OS	SNELLEN OD	SNELLEN OS
Mean	0.83 ± 0.23	0.86 ± 0.23	0.94 ± 0.15	0.94 ± 0.15
Standard error	0.02	0.02	0.02	0.02
Sample variance	0.05	0.05	0.02	0.02
Kurtosis	0.21	2.47	4.38	4.01
Skewness	-1.00	-1.6	-2.34	-2.24
Confidence level (95.0%)	0.05	0.05	0.03	0.03

OD, oculus dexter; OS, oculus sinister.



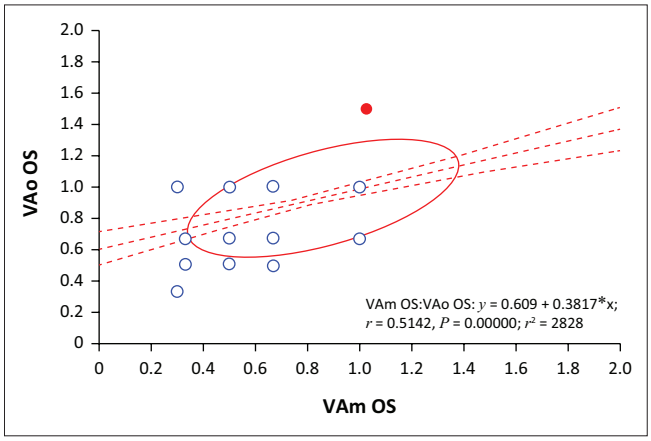
Note: Scatterplot of VAo OD against VAm OD VA2023 4v*100c VAo OD = 0.6929+0.2978*x; 0.95 Conf.Int.

VA, visual acuities.

FIGURE 1: Correlation of visual acuities of OD using First 3D™ (automated) vs Snellen (manual).

Limits of agreement between the First 3D™ and manual methods for the visual acuity measurements

As shown in Figure 3 and Figure 4, only three data points fall outside the upper and lower LoA, indicating that more than 95% of the observations lie within the expected range. The mean differences of –0.12 (OD) and –0.075 (OS) suggest that the two measurement techniques give very similar



Note: Scatterplot of VAo OS against VAm OS VA2023 4v*100c VAo OS = 0.609+0.3817*x; 0.95 Conf.Int.

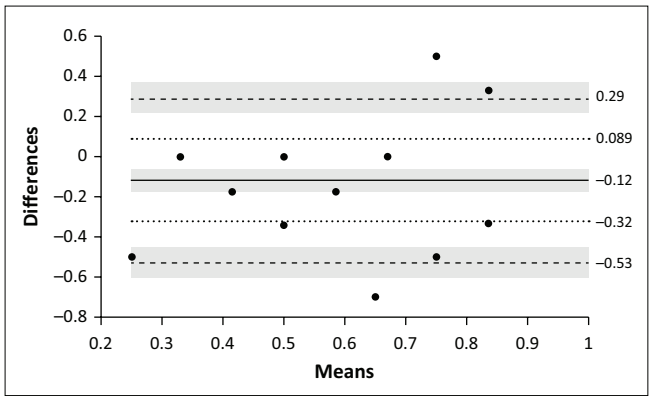
VA, visual acuities.

FIGURE 2: Correlation of visual acuities of OS using First 3D™ (automated) vs Snellen (manual).

TABLE 2: Descriptive data for the visual acuities measured using the automated First 3D™ and Snellen chart.

Descriptives	1ST 3D™ OD	1ST 3D™ OS	NOVIS OD	NOVIS OS
Mean	84.12 ± 3.15	83.92 ± 3.97	82.29 ± 6.99	82.92 ± 5.59
Standard error	0.32	0.40	0.71	0.57
Sample variance	9.90	15.74	48.92	31.29
Kurtosis	15.08	18.31	33.47	24.47
Skewness	-3.95	-4.19	-5.11	-4.46
Minimum	70.00	60.00	30.00	45.00
Maximum	85.00	85.00	85.00	85.00
Confidence level (95.0%)	0.63	0.80	1.41	1.12

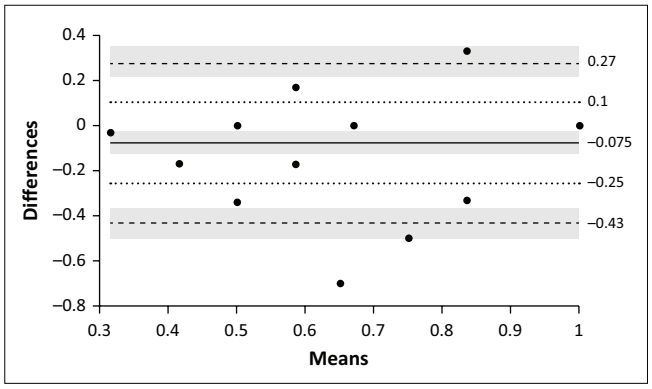
OD, oculus dexter; OS, oculus sinister.



Note: r = 0.49, P = 3e-07.

Manual measurements of OD were subtracted from the automated measurements of OD. The y-axis shows the differences in measurements, while the x-axis shows the means. The solid line represents the mean difference (–0.12). The dotted line represents the standard deviation (s.d.) (0.089–0.32). The dashed line represents the limits of agreement (LoA) (0.29–0.53).

FIGURE 3: Bland–Altman plots for 100 right eyes.



Note: r = 0.39, P = 5.5e-05.

Manual measurements of VAs in decimal notation OS(m) were subtracted from the automated measurements OS. The y-axis shows the differences in measurements, while the x-axis shows the means. The solid line represents the mean difference (–0.075). The dotted lines represent the mean ± s.d. (standard deviation) (0.1–0.25). The dashed line represents the limits of agreement (LoA) (0.27–0.43).

FIGURE 4: Bland–Altman plots for OS.

results on average, with minimal systematic bias. The s.d. of the differences (0.20 for OD and 0.17 for OS) further indicate low variability between the two methods. However, the LoA (0.29–0.53) for OS, P = 0.000) demonstrates a fairly weak agreement, meaning that individual measurements are not consistently close between the two methods. By contrast, Pearson's correlation coefficients (r = 0.44 for OD, r = 0.54 for OS, P = 0.00) show a moderate positive linear association between the two techniques. This suggests that while the methods trend together, their agreement at the individual level is limited, and they may not be directly interchangeable.

Discussion

Studies comparing drivers' vision screenings between automated and manual evaluations are rare. Our study found that the mean manual measurement was higher than that of the automated First 3D™, except for the VF measured for OS, where the mean machine measurement was slightly higher than the manual measurement. Findings from this study provide meaningful insights that could guide future practitioners towards a greater understanding of the balance between manual and automated vision screening testing for drivers.

Visual acuities collected manually were found to be less variable compared to the automated data, contrary to the findings of the study conducted by Metsing, Hansraj & Jacobs.[21] Nonetheless, in their study, they compared the Snellen VAs to the automated Spectrum LogMar Chart. This discrepancy may arise from differences in the level of human intervention in manual measurements, which could contribute to more consistent results because of a standard protocol followed by trained professionals. In contrast, automated systems, while offering greater efficiency and reduced potential for human error, may introduce variability related to the machine's calibration, sensor precision or environmental factors such as lighting.[18,21] Furthermore, automated systems often lack the nuanced judgement that a skilled clinician might apply in situations where minor adjustments or compensations for patient behaviour are necessary. These factors suggest that the variance in automated data may stem from technical limitations or less controlled conditions compared to the manual procedure.

However, less variability using the automated method could be attributed to the software programme found to maintain a consistent ratio between optotypes and spacing, irrespective of the angular subtense of the optotype, compared to the manual method, where each letter is assigned an individual score.[18,22,23,24] However, the manual VAs measured in this study were found to be consistently high compared to the automated data, which could be highly dependent on the skills of the data collector. Furthermore, the slightly lesser VAs measured with the automated method could be attributed to the lack of the 6/7.5 line compared to the manual findings. In addition, the differences could be attributed to the VA of 0.8 (6/7.5), which could not be obtained using the automated vision screener and was recorded as a VA of 0.67 (6/9). Although statistically significant differences were determined between the manual and automated VAs, the level of agreement was found to be very low. However, the manually measured VAs are regarded as the gold standard as they rely heavily on the examiner's skills and experience.[25] Nonetheless, both eyes showed positive correlations between the manual and automated VA measurements. The scatter plots further supported this link, showing a tendency for manual measurements to report better VAs and a trend closer to the ideal automated 6/6.[24,25]

The T-stat's indication of the clinical significance of the mean differences offered strong proof that the observed differences were not the result of random chance. The significant T-stat values gave weight to the observed differences in data means, underscoring the need for careful consideration of these differences in clinical and research settings. For the measurement of VA, the T-stat value was positioned to the left of the mean value and was therefore negative; this indicated a reversal in directionality but did not have a significant impact on the groups. The fact that

this value was shifted away from the mean values supported the idea that manual measurements may be prone to a 'ceiling effect', which may have led to an overestimation of VA.[26,27]

A statistically significant ($P = 0.02$) relationship was found between the automated and manual VFs of OD, with a weak positive correlation coefficient of 0.36. However, OS VFs evaluated using the automated and manual methods showed no statistical significance ($P > 0.05$). Thus, the differences between VFs measured for OD and OS could be attributed to eye dominance. The influence of eye dominance on visual performance and fixation stability could be attributed to the dominant eye's tendency to exhibit more stable fixation, which could potentially lead to more consistent results during vision testing.[28] While our study primarily focused on comparing the outcomes of automated and manual VF tests, Elliot and Harris's study highlights how eye dominance affects not only fixation but also how visual tasks are performed. This distinction could offer valuable insights into understanding why discrepancies between the eyes may arise, particularly when assessing the consistency of results using the two testing methods.

The automated measurements are considered to be capable of eliminating subjectivity encountered with the manual assessment and producing more consistent results.[29,30] The findings of this study corroborated these claims as the automated measurements had numerous narrower ranges and more skewed distributions than the manual measurements. Furthermore, the manual measurements of the VFs are usually performed using mobile targets (kinetic perimetry), similar to the Novice™ sphere target. According to Walsh,[31] the rate of motion and direction of targets when manually evaluating the VFs are controlled by skilled clinicians, who most likely adapt their strategy to maximise the patient's best performance.

The two methods (automated and manual) for measuring the VF in this study were found to yield measurably different results ($P = 0.02$) in contrast to the findings of the study conducted by Odom, Charlton and Leys,[32] who concluded in their study findings that the two methods could be considered comparable on condition that the limitations and sources of bias are acknowledged. However, their study did not demonstrate perfect accuracy, and the automated VF measurements were found to exhibit a narrower range of values compared to the manual method. This indicates possible limitations in the precision of the automated measurements. The contradictory findings on the OD and OS of both the automated and manual evaluations of VFs indicated a complicated relationship between the two methods. Therefore, this allowed for questions and further investigation regarding the accuracy of the manual versus the automated VF tests. When both the Bland–Altman and ANOVA P-values are ≈ 0.000, it means the two methods differ significantly in their average readings. Thus, they show a systematic bias and cannot be used interchangeably without correction or calibration.[19]

Automated and manual VA measurements exhibited a linear relationship, which was favourable to the machine measurements as it demonstrated proportionality to the manual data. However, the left eyes showed a higher association than the right ones. Further research will be required to comprehend this disparity fully, but potential explanations include testing protocol, machine testing habit or fundamental physiological variations between the left and right eyes and eye dominance patterns noted in normal human physiology.

Limitations

This study's limitation was the machine's inability to measure the 6/7.5 line of VAs, making it difficult to capture the complete range of VAs and compare them to the manual VAs. The evaluation of the VFs using the Novice Sphere is also a limitation because of the lack of literature on the instrument's accuracy and reliability. Determination of the dominant eye could also have provided the explanation related to the statistical significance differences for the VFs between the manual and automated methods for OD and OS. Inter-examiner variability was not assessed, which may have influenced the consistency of the measurements and the comparability of results across different examiners. Additionally, because of the limited range of VF measurements captured and the study design involving single measurements per participant, methods such as Bland–Altman or ICC were not applicable. A lack of calibration of automated measurements represents a limitation of this study, as appropriate calibration could have improved the comparability of the automated findings with those obtained using the manual method.

Conclusion

Although automated and manual methods demonstrated trends in the same direction, especially for VA measurements, the level of agreement between the two methods was found to be weak, thus indicating that the two methods for individual VA assessments should not be used interchangeably. While no statistically significant differences were identified between the manual and automated VF testing methods, variations related to test sensitivity, examiner judgement, eye dominance, lack of calibration and procedural factors highlight the need for cautious clinical interpretation. Although automated systems offer efficiency and consistency, they may miss subtle VF defects that a skilled clinician might identify because of factors like patient behaviour, test environment or variability in reliability. Clinical judgement remains essential, especially in detecting early or borderline VF changes.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Thokozile I. Metsing: Methodology, Formal analysis, Writing – original draft, Data curation, Writing – review & editing. Nabeela Hasrod: Conceptualisation, Formal analysis, Writing – original draft, Validation.

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Data availability

The data that support the findings of this study are available from the corresponding author, Thokozile I. Metsing, upon reasonable request.

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