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REVIEW

Mobile Apps and Visual Function Assessment: A Comprehensive Review of the Latest Advancements

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ABSTRACT

Introduction: With technological advancements and the growing prevalence of smartphones, ophthalmology has opportunely harnessed medical technology for visual function assessment as a home monitoring tool for patients. Ophthalmology applications that offer these have likewise become more readily available in recent years, which may be used for early detection and monitoring of eye conditions. To date, no review has been done to evaluate and compare the utility of these apps. This review provides an updated overview of visual functions assessment using mobile applications available on the Apple App and Google Play Stores, enabling eye care professionals to make informed selections of their use in ophthalmology.

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Methods: We reviewed 160 visual function applications available on Apple iTunes and the Google Play Stores. The parameters surveyed included types of visual function tests, the involvement of healthcare professionals in their development, cost, and download count.
Results: Visual tests, including visual acuity and color vision tests, were most common among apps surveyed, and they were comparable to traditional clinical methods. Certain applications were more widely used, some of which have had studies conducted to assess the reliability of test results. Limitations of these apps include the absence of healthcare professionals' involvement in their development, the lack of approval by regulatory authorities and minimal cloud-based features to communicate results to healthcare professionals.
Conclusions: The prevalence and easy access of visual function testing applications present opportunities to enhance teleophthalmology through early detection and monitoring of eye conditions. Future development to enhance the quality of the apps should involve regulatory bodies and medical professionals, followed up by research using larger samples with longer follow-up studies to review the reliability and validity of ophthalmology applications. This would potentially enable these applications to be incorporated into the comprehensive assessment and follow-up care of patients' eye health.

Keywords: Mobile applications; Teleophthalmology; Visual function test

Key Summary Points

Visual function apps have grown in recent years and may potentially be used in ophthalmology for early detection and monitoring of eye conditions. There is no review to evaluate and compare the utility of these apps.

This review provides an updated overview of the features of visual function apps, enabling eye care professionals to select suitable apps for clinical use.

Several apps were able to assess visual acuity, color vision, macular function (Amsler grid test), and contrast sensitivity, comparable to traditional clinical methods. However, greater challenges were experienced in using apps for visual field testing.

Some apps for visual field testing faced greater challenges in accuracy. Some had an area under the receiver operating characteristic (AUROC) bellow 0.65 for detecting visual field defects, with only 35% sensitivity for moderate or worse glaucoma, highlighting the need for improvement.

Few apps involved eye professionals in their development and received approval by health regulatory authorities to be used as medical devices.

Future research is needed to enhance the utility of these apps, including clinical validation on larger samples and involving the expertise of eye professionals in their development.

INTRODUCTION

Vision impairment is a global issue with a significant economic burden on individuals, healthcare workers, and society [1]. This is an issue both in developing countries, where poor access to healthcare limits treatment of preventable causes of visual impairment [2], as well as developed countries with an increased prevalence of age-related diseases including cataracts, age-related macular degeneration, and glaucoma [3]. This is anticipated to increase demand for eye care and potentially place further strain on the healthcare system. Therefore, it is imperative to seek alternative self-monitoring methods for visual functions to allow early detection and timely treatment of these conditions [4].

With rapid technological advancements and the incorporation of digital innovation into healthcare [5], portable devices including smartphones have been utilized in ophthalmology to create telehealth programs and eye screening tools [6]. Given that 83.72% of the global population owns a smartphone [7], this represents a significant opportunity to use the smartphone as a platform for improving access to medical care by allowing earlier detection and treatment of diseases. However, few ophthalmology applications have shown significant success in detecting ophthalmological conditions [8]. This limits their utility to ophthalmologists as a screening tool to identify ophthalmological diseases and monitor the progression of these diseases. To date, no comprehensive reviews have been done to evaluate and compare the features of currently available visual function test applications.

In this article, we review and evaluate the efficacy of the currently available eye tests and monitoring tools offered by smartphone applications. This overview of the developments in visual functions applications would enable eye care professionals to better select reliable and accurate mobile visual apps to enhance clinical practice, as well as identify gaps for future development and research.

METHODS

A search was performed on the Singapore Apple (Apple, Cupertino, CA, USA) iTunes Store and the Singapore Google Play Store (Google, Mountain View, CA, USA) from May 1 to June 30, 2022, for eye-care-specific applications. The search was performed via a Singapore-based Internet Protocol (IP) address, thus only applications available in Singapore or globally were included in the search. Applications unavailable in Singapore, either due to regional restrictions or developer preference, were not included in the study. The App Store was searched using the pre-installed App Store application on an iPhone XR (iOS15.0). The Google Play Store was searched using the Google Play website via a Google Chrome browser on a Windows personal computer, displaying applications available for installation on the Android 12 operating system. The same search parameters were used for both application stores.

Inclusion criteria comprised the applications that resulted from the following search terms: Vision, eye test, eye exam, visual acuity, Snellen, logMAR, contrast sensitivity, Amsler grid, color/color vision, color/color blind, red saturation, contrast sensitivity, Ishihara, Worth 4 dot, stereoacuity, visual field, binocular single vision, strabismus. Exclusion criteria included the following types of applications: non-ophthalmic related applications, mobile games, advertisements, camera filters, phone screen filters, augmented reality applications, eye exercise applications, non-English applications and applications not available on the Singapore version of the application platforms. Applications that require synchronization with specialized equipment such as screens were also excluded.

Information on the following parameters were extracted from the applications to review their utility. These parameters were identified based on the expertise of ophthalmologists (RA, BA) as essential for ophthalmologists in considering their usefulness for patient care.

1. Number and type of visual function tests offered
2. Ability to store user test results and/or communicate results to healthcare provider
3. Type and inclusion of healthcare professional involvement in application development – this was assessed based on the application description in the store, disclaimer text and/or any associated application website
4. Whether clinical trials have been performed
5. Cost of applications and in-application purchases
6. Number of downloads of each application

This review was based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors. Therefore, no ethical approval from an ethics board was required.

RESULTS

A total of 160 applications were found between the Apple App Store and the Google Play Store. 58 were available only on the Apple App Store, 88 were available only on the Google Play Store, and 14 on both platforms. Results of the search strategy are described in Fig. 1. An overview of the data collected in this survey is represented in Supplementary Materials Table S1.

Types of Visual Function Tests

From all the apps reviewed, 75.63% (n=121) provided only a single visual function test, 8.75% (n=14) and 7.50% (n=12) apps provided three and four or more visual function tests, respectively. A summary of the visual function tests offered by applications across both platforms is shown in Fig. 2. Visual acuity (VA) (n=83) and color vision (n=80) were the most commonly tested functions found among the applications analyzed. Less commonly found functions were: Strabismus (n=5), Worth 4 dot (n=5), Red desaturation (n=5), and Stereoacuity (n=3). Some applications featured multiple visual acuity or function tests.

Only 12 of the applications surveyed were able to store users' test data for review at a later date. Of these, two applications—OdySight® and Paxos Checkup Mobile Application—offered cloud-based servers to communicate test results to a healthcare professional.

Involvement of Healthcare Professionals and Clinical Trials

Of all the apps, 85.63% (n=137) were developed without known healthcare professional input; 1.25% (n=2) were developed with the input of non-eye care healthcare professionals (e.g., ophthalmic technicians), and 13.13% (n=21) involved an eye-care professional (ophthalmologist, optometrist) in their development; 11.87% (n=19) of the applications surveyed have had clinical trials performed, while the remaining 88.13% (n=141) of applications have not had clinical trials performed at the time of survey. Only three ophthalmic mobile applications have received Food and Drug Administration (FDA) approval for use as a medical device as of 2018 [9].

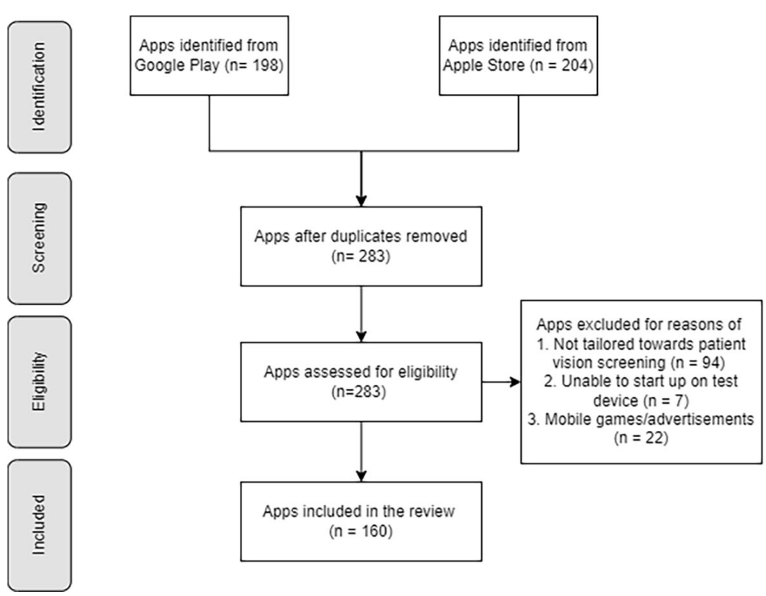

Fig. 1 Summary of search strategy and results, guided by PRISMA flow chart

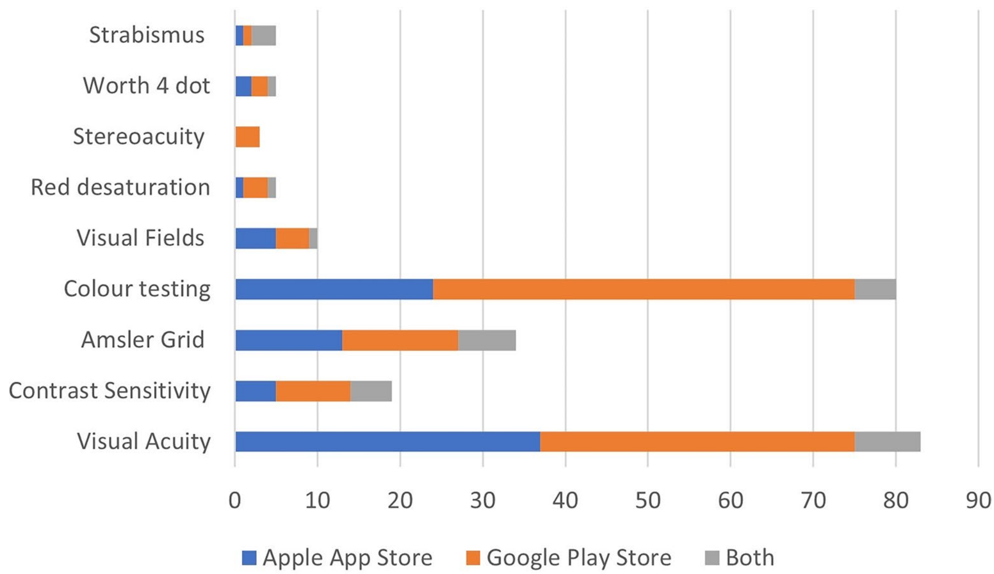

Fig. 2 Number of visual function tests offered by applications, classified by platform

Cost of Application and Download Count

Among the apps surveyed, 16 applications were paid applications, while 11 required in-app purchases to unlock full functionality (range of features and capabilities offered by these applications). A further three applications required the purchase of external devices for app usage. The remaining 130 apps were free to use.

The number of downloads of each application was restricted by limited data provided by each app store. While the Google Play Store provides download count ranges (i.e., 1000+, 5000+, 10,000+), the Apple App Store does not make download counts available to public access. Among the apps featured on the Google Play Store, three apps ranked the highest in terms of download counts—Eye exam (Andrew Brusentsov) (1,000,000+ downloads), Eye test (Designveloper) (1,000,000+ downloads) and Visual Acuity Test (healthcare4mobile) (500,000+ downloads).

Visual Function Apps Available in Singapore

Figure 3 depicts an overview of the visual function testing apps available in Singapore.

Visual Acuity

The visual acuity test is one of the most important standard psychophysical tests for evaluating visual functions and is usually performed by a trained ophthalmic practitioner to determine the patient's ability to discriminate details [10]. Portable smartphones and tablets with high-resolution screens have encouraged the development of mobile applications, which provide a new alternative to traditional methods of VA testing [8]. Commonly used applications for VA testing are Peek Acuity, Sightbook application and EyeChart application as shown in Table 1 [11–15]. Clinical trials have found that the measurements differ significantly between the Rosenbaum near vision chart of the Sightbook compared to the Snellen chart. The Peek Acuity demonstrated good agreement against the Early Treatment Diabetic Retinopathy Study (ETDRS) chart and against Snellen acuity data at 0.07 (95% CI 0.05–0.09) and 0.08 (95% CI 0.06–0.10) logMAR, respectively [13]. There was a strong correlation between results of Eyechart application and Snellen ($r = 0.79$, $p < 0.01$) and ETDRS charts ($r = 0.88$, $p < 0.01$) but no statistical difference between VA measurements of Eyechart and ETDRS chart ($t = -2.39$, $p = 0.08$) [15]

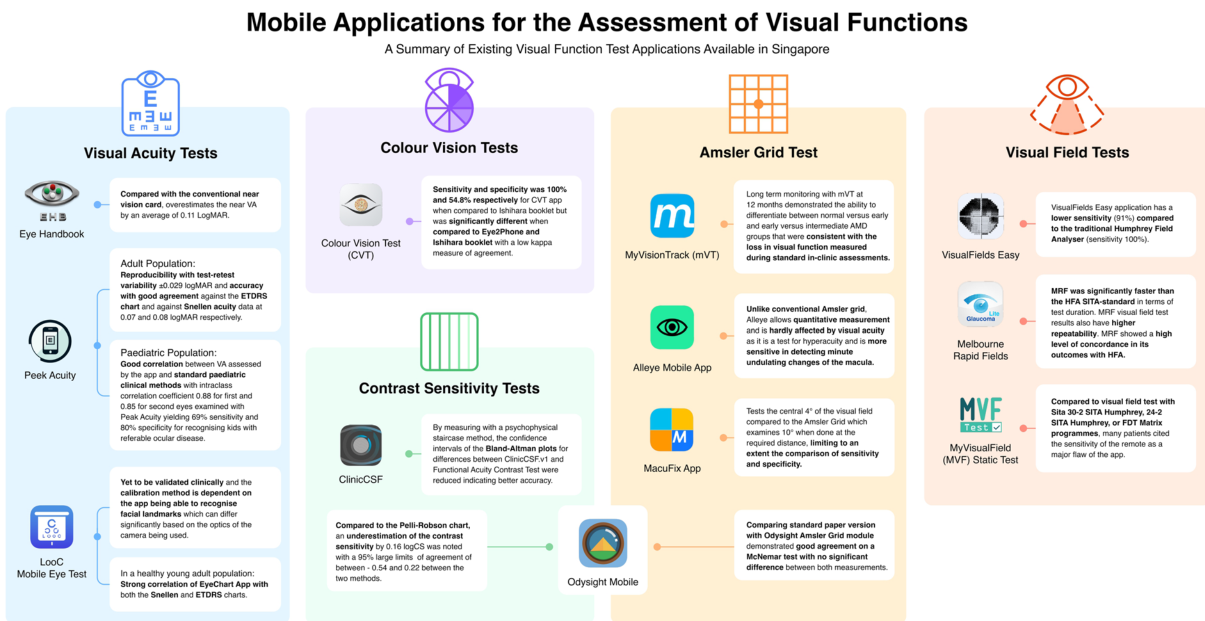

Fig. 3 Overview of visual function testing applications commonly used in Singapore

However, these applications have varying accuracy levels for different participant age groups when conducted by trained versus untrained practitioners and between tablets versus smartphones, with increasing sensitivity, specificity, and diagnostic odds ratio found with increasing age [8].

Color Vision

Color vision assessment is commonly performed during routine eye examinations. Frequently used tests include pseudoisochromatic plate tests such as the Ishihara test [16], which is the most commonly used, the Hardy–Rand–Rittler (HRR) test [17], and color arrangement tests, such as the Farnsworth–Munsell 100 hue test [18]. Similar to VA tests, the pseudoisochromatic tests are easily replicated on smartphones and thus widely available, with 80 visual function applications surveyed offering color vision tests (see Table 2). Recent smartphone displays use variants of liquid crystal display (LCD) or light emitting diode (LED) technology (e.g., thin-film transistor LCD (TFT-LCD), organic-light emitting diode (OLED) [19]. When administering color vision tests on such displays, care should be taken in standardization of these tests as change in ambient illumination level and luminance contrast ratio can result in minute but significant effects on visual perception [20].

Amsler Grid

myVisionTrack testing is the most commonly prescribed self-monitoring test offered to patients for qualitative assessment of macular function and to detect early signs of macular diseases [21]. It often manifests as symptoms of scotomas or metamorphopsia involving the central visual field [22]. Amsler grid testing is widely used in clinical practice to monitor macular function by evaluating the eye's hyperacuity—the ability to pick up slight changes in straight lines. It enables early detection of progression in patients with exudative neovascular age-related macular degeneration and diabetic macular edema [23]. This simple test can be easily replicated on smartphones and is thus widely available in the current selection of applications available, as illustrated in Table 3 [23–27]

Table 1 Overview of the commonly used applications for visual acuity (VA) testing

Application name	Application overview	Clinical trial findings
Sightbook	Multiple visual function tests: VA, color vision, contrast sensitivity, Amsler grid. Able to log treatments and appointments	Measurements differ significantly between the Rosenbaum near vision chart (5.4 and 6.1 letters for right and left eyes), and the Snellen chart (6.4 and 7.6 letters for right and left eyes) [11]
Eye Handbook	Multiple visual function tests: VA, color vision, contrast sensitivity	Over estimates near VA compared with conventional near vision card by average of 0.11 logMAR (P value < 0.00), suggested to be due to increased contrast level of mobile device screens [12]
Peek Acuity VA	VA testing with Tumbling E chart Requires a second person to operate the application; the patient is unable to perform the test independently	Able to yield reproducibility with test–retest variability ± 0.03 logMAR (95% CI), shows accuracy with good agreement of the application against the Early Treatment Diabetic Retinopathy Study (ETDRS) chart and against Snellen acuity data at 0.07 (95% CI, 0.05–0.09) and 0.08 (95% CI, 0.06–0.10) logMAR, respectively [13]
LooC Mobile Eye Test	Performs distance calibration using front-facing camera for near VA, or measuring phone against computer screen for distance VA	Clinical trial not performed [14]
Eyechart	VA testing via Snellen chart	Strong correlation between results of Eyechart application and Snellen ($r = 0.79, p < 0.01$) and ETDRS charts ($r = 0.88, p < 0.01$), no statistical difference between VA measurements of Eyechart and ETDRS chart ($t = -2.39, p = 0.08$) [15]

Table 2 Overview of the commonly used applications for color vision testing

Application name	Application overview	Clinical trial findings
Eye2Phone	Duplicate of full 38-plate Ishihara test	Compared to Ishihara test—100% (38/38) sensitivity and 95.23% (40/42) specificity with no significant difference ($p = 0.50$), high kappa measure of agreement (0.95, $p < 0.001$) [19] Unable to differentiate specific types of dichromatism Found to be less comfortable and clear compared to the physical Ishihara booklet by subjects
Color Vision Test	16-plate pseudoisochromatic plates, multiple choice answering style with six different possible answers for each plate	Compared to Ishihara test – 100% (38/38) sensitivity and 54.76% (23/42) specificity, low kappa measure of agreement (0.54, $p < 0.001$) Unable to differentiate specific types of dichromatism [19]

Contrast Sensitivity

Contrast sensitivity function (CSF) measures the threshold contrast needed to detect stimuli of differing spatial frequencies [28]. CSF is a better predictor of visual performance and provides more information than visual acuity, which only measures sensitivity at high spatial frequencies [29]. Charts often used in the clinical setting include the Pelli–Robson contrast sensitivity test, functional acuity contrast test (FACT), and the Mars contrast sensitivity test. However, such specialized charts are not readily available in common practice [30, 31]. An overview of the contrast sensitivity tests is shown in Table 4 [26, 32–34].

Visual Field

Visual field refers to the portion of space in which objects are visible at the same moment during steady fixation of gaze in one direction. Visual field assessment hence refers to the assessment of the field of vision, which can provide important information for the assessment of ophthalmological conditions including retinal and optic nerve pathologies. Visual field testing can be done either simply at the bedside with confrontational tests, or in a more detailed manner via manual or automated perimeters [35].

Manual perimetry refers to the presentation of a spot of light of adjustable size and intensity presented to the patient on a uniform background illumination. The light stimulus is moved from the periphery into the field of vision slowly, with the patient indicating his ability to visualize the spot of light with a buzzer. Automation of perimetry is an important development in the field of visual field assessment. This refers to the automation of target presentation in visual field assessment, such that the results of the visual field test can be compared between the individual patient and a normal population [35].

An important consideration in visual field testing is ensuring the maintenance of fixation throughout the duration of the test. This has been recognized as a major challenge to performing visual field testing via mobile applications. Virtual reality (VR) is an emerging technology which, when used in conjunction with mobile application visual field testing,

Table 3 Overview of the commonly used applications in myVisionTrack testing

Application name	Application overview	Clinical trial findings
Alleye	Assesses Vernier visual acuity – users required to align middle dot with 2 outer dots on invisible straight line Covers 12.7° – screens nearly entire macular area Received FDA approval in 2018	High accuracy in detecting wet AMD with an area under the curve (AUC) (95% confidence interval) to identify wet AMD of 0.85 (0.76–0.93) Reasonable accuracy in classifying dry and wet AMD with AUC (95% confidence interval) of 0.66 (0.52–0.80) [23]
myVisionTrack® (mVT)	Assesses hyperacuity via shape discrimination Tests 3° visual field	Able to monitor diabetic macular edema patients for progression and response to anti-VEGF therapy – with improvement of 0.15 ± 0.17 logMAR ($p < 0.006$) at 3 months and 0.13 ± 0.18 logMAR (p < 0.02) at 6 months compared to clinical judgment of change [24]
Paxos Checkup	Digital version of Amsler grid Able to securely transmit results to Paxos cloud-based patient management system shared with physicians	Strong agreement when compared to Amsler grid testing – sensitivity 93%, specificity 92% ($r = 0.96$) [25]
Odysight	Digital version of Amsler grid Results are accessible to assigned physicians via cloud system	Good agreement with Amsler grid test with no significant difference ($p = 1.0$) between the test results [26]
MacuFix®	Utilizes algorithm establishing smallest noticeable distortion difference – categorized as MacuFix Class (MC) AMD-A Metamorphopsia Detector® provides a Metamorphopsia Index (MI) comprising of the extent, eccentricity and region of metamorphopsia Tests central 4° of visual field	Demonstrates reliability in detecting metamorphopsia with excellent intraclass correlation coefficient of MI and MC for eyes with metamorphopsia in the central 4° (ICC 0.98 (confidence interval CI 0.65; 1.00; $p < 0.01$)) [27]

Table 4 Overview of the commonly used applications for contrast sensitivity function (CSF) testing

Application name	Application overview	Clinical trial findings
Odysight	Designed with Landolt C optotype with varying directions and contrast levels based on Pelli–Robson contrast sensitivity chart	Underestimates contrast sensitivity by 0.16 logCS (95% CI 0.20–0.13) when compared with Pelli–Robson chart, with 95% limits of agreement of between 0.54 and 0.22 between the two methods [26]
ClinicCSF	Assessment of CSF with 9 patches of sinusoidal gratings with varying spatial frequencies	ClinicCSF.v2 was able to obtain similar scores to functional acuity contrast test (FACT) for all the evaluated spatial frequencies in subjects evaluated ($p > 0.05$) ClinicCSF.v1 (previous version) obtained higher median CSF values compared to FACT for all frequencies except 3 cycles per degree ($p < 0.001$) [32] – attributed to ClinicCSF.v1 measuring different CS levels from FACT, and employing different psychophysical methods
Peek contrast sensitivity (PeekCS)	Assesses CSF with tumbling "E" chart displayed at progressively decreasing contrast level	Demonstrates strong repeatability (correlation coefficient: 0.93; 95% CI: 0.91–0.95) comparable with Pelli–Robson CS test (PRCS) (correlation coefficient: 0.96; 95% CI: 0.95–0.97) with measurements highly correlated to each other 0.94 (95% CI: 0.93–0.95); 95% limits of agreement − 0.27 to 0.29; and mean difference of 0.01 (95% CI: − 0.00 to 0.02) [33] Shorter testing time (44.6 s) compared to PRCS (48.6 s) [33]
Aston contrast sensitivity Near Application/distance chart	Demonstrates all contrasts and spatial frequencies in one display using swept frequency display on device screen Comprises of a pair of applications – serve to assess contrast sensitivity for both near and distance vision Able to instantaneously plot test results	Demonstrates greater efficiency – able to assess more spatial frequencies in a shorter time (CSV-1000 was 124 ± 37 s, Pelli–Robson 78 ± 27 s, near application 53 ± 15 s and distance application 107 ± 36 s) Demonstrates higher repeatability (repeatability coefficient near: 0.26 to 0.37 log units; distance: 0.34 to 0.39 log units) when compared to CSV-1000 (0.30 to 0.93 log units), but lower repeatability when compared to Pelli–Robson [34]

has the potential to replicate the reliability of Humphrey's perimeter [36]. However, there are limitations in current technological capability—many currently available VR setups are unable to assess the peripheral and mid-peripheral visual field areas [36]. A summary of the visual field tests is shown in Table 5 [37–40].

DISCUSSION

Traditional ophthalmic equipment has limited portability, restricting their use to only the traditional clinical setting. The development of novel mobile device eye-screening applications has the potential to overcome this limitation, allowing access to accurate screening tests even outside the eye clinic [8]. With the extensive options available, it is important for practitioners to trust and understand the functionality of the applications before choosing a suitable and reliable application for their daily practice and recommend appropriate ones to patients for self-monitoring. The selection of such an application would require many considerations, including accuracy and reliability of tests administered, user-friendly user interface, as well as additional features such as the ability to store results and communicate them to a healthcare provider. This review adds knowledge on the latest developments of visual function apps and summarizes key features that are essential in considering their selection by eye care professionals.

Firstly, this study found that several apps were able to record testing results comparable to traditional clinical methods of assessing visual acuity, color vision, Amsler grid testing and contrast sensitivity. On the other hand, visual field testing in mobile applications is still a modality which faces challenges including maintenance of fixation during testing as well as the ability to assess the peripheral visual field [36]. A suggested solution to this is the use of virtual-reality technology to aid in visual field testing, however this has also been found to have limitations in assessment of peripheral and mid-peripheral visual field areas [36]. The use of virtual reality in visual field testing is also a relatively new technology which has yet to undergo extensive testing for its ability to replicate results from tradition visual field assessment modalities.

Secondly, only few applications featured cloud-based capability such as Odysight where data from a patient's self-monitoring are channeled via a secure server to a dashboard in the clinic, which will prompt the practitioner and patient should there be a significant decline in results [26]. This added benefit potentially facilitates real-time communication between the patients and practitioner, allowing better management for patients who may require earlier attention. This essential component of their platform that facilitates communication and provides better monitoring with auto-alerts should be integrated into all healthcare applications. However, additional cost and complexity of ensuring a secure system may pose a challenge.

The UK Medicines and Healthcare products Regulatory Agency (MHRA) and US Food and Drug Administration (FDA) are a few authorities that register and regulate health applications. A health application must fulfil certain criteria before it can be registered and get a CE certification. Despite the rapid advent and widespread availability of eye-screening applications, only three ophthalmic mobile applications have received FDA approval for use as a medical device as of 2018 [9]. To our knowledge, no further ophthalmic mobile applications have received FDA approval since. Many applications are unregistered and yet appear on the "Health" categories of application stores. This may mislead users regarding the accuracy and reliability of test results obtained via these applications. It is thus essential for ophthalmic practitioners to analyze and be aware of the clinical validity, accuracy and safety of such applications. Application developers will need to further improve the accuracy, conduct longitudinal studies and provide thorough clinical validations of their applications before clinicians incorporate or even fully replace the traditional testing methods for their routine clinical examination.

The quality of the apps is an issue of concern as only 13.1% of apps surveyed in this study involved eye-healthcare professionals in their development. This is reflected in a similar study done on 182 eye care-related iPhone

Table 5 Overview of the commonly used applications for visual field testing

Application name	Application overview	Clinical trial findings
visualFields Easy	Subject instructed to fixate on central red dot, and register input when white dot can be seen in periphery	Achieves area under the receiver operating characteristic (AUROC) curve of 0.64 (95% CI: 0.57 to 0.71) for detection of any visual field defect relative to Humphrey field analyser (HFA) At set specificity of 90%, sensitivity of 35% for moderate or worse glaucoma [37]
Melbourne Rapid Fields (MRF)	Uses radial pattern centered at fixation, assesses loss of sensitivity in macular and paramacular regions. Peripheral vision assessed by changing the location of the fixation point—allows for VF testing up to 34° horizontal and 25° vertical Does not assess fixation, plays voice recording at intervals reminding subject to fixate	Test duration significantly faster than HFA SITA-standard (MRF 4.6 ± 0.1 min vs SITA-standard 6.2 ± 0.1 min, $P < 0.001$) [38] Higher repeatability with intra-class correlation (ICC) for baseline and the 6-month visit being 0.98 (95% CI: 0.96–0.99), compared to 0.95 for SITA-fast and 0.93 for SITA-standard [38] Significant rate of fixation losses (39.3%) [38]
StrokeVision Mobile Application	Developed to facilitate screening for post-stroke visual impairment Uses central smiling face graphic as fixation target, black circular target emerging from periphery to test peripheral vision	Achieves sensitivity of 0.71 (95% CI: 0.48–0.89) and specificity of 0.71 (95% CI: 0.48–0.89) when compared to Goldmann or Octopus visual field testing apparatus [39]
myVisualField© static test	Performed with smartphone and virtual reality (VR) visor to detect visual field defects	Clinical trial performed did not perform comparison of results with traditional visual field testing modalities [40]

(Apple, Cupertino, CA, USA) applications, where only 37% had reported qualified professional involvement in their development, suggesting that this an unregulated field with applications of varying quality [8]. Quality of applications can potentially be improved via the following methods: firstly, regulators, practitioners and patients should be involved in the development and testing of the applications [41]; secondly, a system of active feedback and reporting of safety concerns from both patients and practitioners regarding eye care mobile applications should be implemented to ensure their safe usage [41]. Lastly, guidelines in selection and usage of the appropriate applications should be made available for practitioners' reference [42].

Real-Life Implications and the Need for Enhanced Diagnostic Accuracy in Mobile Eye Testing Apps.

Applications like Alleye have shown high diagnostic accuracy in detecting wet age-related macular degeneration (AMD), with an area under the curve (AUC) of 0.85 (95% CI: 0.76–0.93) [23], while myVisionTrack effectively monitors diabetic macular edema progression, demonstrating improvements in vision with a mean change of 0.15 ± 0.17 logMAR at 3 months ($p < 0.006$) [24]. However, the diagnostic performance of these apps is often limited compared to gold-standard clinical equipment like the Humphrey Field Analyzer (HFA). For instance, visualFields Easy achieves an AUROC of only 0.64 (95% CI 0.57–0.71) for detecting visual field defects, with sensitivity as low as 35% for moderate or worse glaucoma at 90% specificity [37]. This highlights a trade-off between convenience and precision, especially for critical diagnoses where more accurate methods, such as the HFA, remain the preferred standard of care.

Despite these advancements, the real-life diagnostic accuracy of these mobile applications could benefit from further refinement. Many apps, like the color vision test, show high sensitivity (100%) but relatively low specificity (54.76%), which could lead to a higher rate of false positives [19]. Similarly, Melbourne Rapid Fields demonstrates excellent repeatability, with an intra-class correlation (ICC) of 0.98 (95% CI 0.96–0.99) for baseline and 6-month results but suffers from a significant rate of fixation losses (39.3%) [38]. Moreover, the StrokeVision Mobile Application, used to screen for post-stroke visual impairments, achieves a sensitivity and specificity of 0.71 (95% CI 0.48–0.89), which while moderate, may not be sufficient for accurate diagnoses in all cases [39]. Emphasizing diagnostic accuracy through more rigorous clinical validation and conducting comprehensive comparisons to traditional testing will be crucial for integrating these apps into routine ophthalmic screening and monitoring with greater confidence. Additionally, concerns regarding data privacy and the potential for misdiagnosis if these applications are not used correctly should be highlighted. Misinterpretation of results, particularly in apps with lower specificity or sensitivity, could lead to delayed or incorrect treatment, especially for serious conditions like glaucoma or AMD. Furthermore, with the increasing reliance on cloud-based storage and transmission of sensitive patient data, ensuring robust privacy protections and secure data management will be essential to maintaining patient trust and safeguarding their health information.

Limitations

While there is a large selection of smart portable devices available and constant improvement of screen technologies, the absence of uniformity across different smartphone applications makes it infeasible to evaluate the accuracy of applications across all devices when compared to the gold standard clinical tests. Further studies will be required to assess if the differences in screen size, screen technologies, and angular size difference due to variations in testing distances affect the test results. The application platforms display limited application data such as the application download count. The Apple iTunes (Apple) Store does not display the download count of each application, while the Google Play Store (Google) displays download counts as a range rather than an exact value (e.g., 10,000–50,000 downloads). Lack of information on this parameter does not allow one to know the applications which are more widely used, and possible reasons behind their popularity. Number of search results were limited to the first 150 results for each search term on the Google Play platform, which could have resulted in the omission of some visual function applications from our survey.

Many applications provided only limited details regarding its development. This information was conveyed only via short write-ups in the application store, disclaimer texts in the application as well as an associated website for a minority of applications. As such, certain information regarding an application including the involvement of healthcare professionals in an application's development could be omitted and hence inaccurately represented in our study. In addition, apps falling under the category of "Games" in the app store were excluded from the survey, given that most of these would likely serve a primary purpose of entertainment rather than visual assessment. We do acknowledge that some of these games may have been developed as visual assessments for the pediatric population, and were omitted from this survey. This limits the application of this literature review to the pediatric population. Each application could have been assessed in a more in-depth manner, such as the clarity of instructions given to patients, or the type of visual test used to assess each visual function, such as a Snellen chart for visual acuity. This, however, may have been challenging given the large volume of applications surveyed in this study. Furthermore, new apps may have been developed after the search period, which were not included in this review. Apps that were found on the Google Play Store using a personal computer may also not show up on the mobile-based Android versions, which may limit the applicability of this review for those who intend to use their mobile Android to access these apps. In the future, updates should be conducted to review whether existing apps have been improved or new apps have been developed, as well as to broaden the search to include apps available on the Android platform.

Lastly, we acknowledge that only applications available in Singapore were surveyed. Due to geo-restriction policies employed by both the Apple App Store and the Google Play Store, some applications available in other countries may not be available in Singapore. Certain applications widely used in other countries (but unavailable in Singapore) may thus have been excluded from this study.

CONCLUSIONS

With the increasing aging population worldwide, the prevalence of age-related ophthalmic disease will place a strain on the existing eye care system. Overall, this review has found that the use of visual function test apps shows promise to enhance teleophthalmology and alleviate the increasing strain on the ophthalmic healthcare system. The availability of diverse visual function test apps may provide an economic and readily accessible method for the patient and primary eye care practitioner to detect early and monitor a broad range of eye conditions. Despite the limitations, further developing these visual function apps may support and advance the quality of eye care, especially for remote teleophthalmology and in rural settings. Future work is needed to improve their accuracy to be comparable to current gold-standard methods of eye screening, data-storing capacity, practitioner monitoring capability, and adaptability to varying settings, devices, and users. This would potentially enable these applications to be incorporated widely into comprehensive patient care, leading to a higher quality of sustainable ophthalmic care to enhance patient outcomes.

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Data Availability. All data generated or analyzed during this study are included in this published article or as supplementary information files.

Declarations

Conflict of Interest. Caius Goh, Marilyn Puah, Zhi Hong Toh, Joewee Boon, Debbie Boey, Ryan Tay, Ashita Ashish Sule, Renee Liu, Ong Xing Er, Aditya Kalra, Satvik Gupta, Andres Rousselot, William Rojas-Carabali, and Bryan Ang declare no competing interests. Rupesh Agrawal is an Editorial Board member of Ophthalmology and Therapy. Rupesh Agrawal was not involved in the selection of peer reviewers for the manuscript or any of the subsequent editorial decisions.

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