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SURVEY

XR Review: A Comprehensive Analysis of Visual Function Testing and Gamification in Extended Reality Environments

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ABSTRACT Spatial Computing has been a keen research area for innovations in healthcare due to its perceived virtual world that replicates the real world. The interactions, dimensions, physics can all be based on naturalistic principles. Extended Reality (XR) is a key element of spatial computing that includes Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR). Due to the potential of creation of realistic virtual world, healthcare applications that are gamified have come into light. Visual function testing is one of the applications which has a scope for designing a gamified testing in XR for the users' portable eye testing at comfort of their home. However, a significant gap exists in the designing and understanding of these applications. This study examines 59 research papers discussing visual function testing and gamification in XR. The corpus has been reviewed for the devices used, accuracy obtained compared to gold standards, usability and game mechanics. Based on these, this review discusses the design consideration needed in developing a gamified XR visual function testing application to enhance the accuracy and engagement of the testing in the users.

INDEX TERMS Extended reality, gamification, low vision aids, vision testing, serious games.

I. INTRODUCTION

The current global world involves around 2.2 billion people who are suffering from near or distance visual impairment, with at least 1 billion of these could have been prevented and treated before it worsened [1]. Study showcases the constant rapid growth of visually impaired people in India of which 92% could have been prevented [2]. Vision loss can transpire at any age levels. However, with rising cases in visual impairment, there is a constant urge in getting treated at the initial stage of visual impairment. Pandemic had imposed various difficulties and challenges for a frequent and a regular vision testing in person at clinics. Hence to overcome such challenges, a need for automated home based portable testing arises.

Various categories of visual impairments are present ranging from blurry eyes to peripheral vision loss. Visual Impairments such as Refractive error, cataract, presbyopia, glaucoma, diabetic retinopathy etc., can lead to irreversible blindness. These major visual impairments if treated at an early stage & with regular checkups can prevent permanent blindness. Two such major visual impairments have high rate of increasing population and vision fatality: Glaucoma (peripheral visual field (VF) loss, especially in adults above 60 years) and loss of Visual Acuity (VA) [3], [4]. The current standard for testing glaucoma includes various perimetry devices like Humphrey Visual Field Analyzer and Goldmann perimetry. These are high-priced, uncomfortable and time-consuming testing devices available in clinics

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[5], [6]. Besides glaucoma testing, Visual acuity tests such as reading optotype charts can be boring for young children and may lead to incorrect assessment. Additionally, these conventional testing with clinician monitoring at clinics lead to lack of motivation for frequent testing in various age groups. Observed uncomfortability during these tests decreases the patient's attention which may lead to fixation errors or false positives [7], [8]. Consequently, Extended Reality (XR), with the help of its depth perception and naturalistic display and interaction fidelity can replicate these testing scenarios [9]. Furthermore, it can be used as an automated portable testing device for Glaucoma and visual acuity along with gamification techniques (game mechanics) to reduce boredom [10], [11] for better testing frequency resulting in better test accuracy.

A considerable number of XR gamified visual function testing has been designed by various works who have achieved good results [12], [13], [14], [15]. The prolonged head fixation during the testing can be resolved in XR by accordingly designing the virtual environment test scenario. Extended Reality, being an element of spatial computing, provides a virtual environment for the user to interact through Head Mounted Displays (HMDs)/wearables and controllers (sensors & trackers). Virtual Reality (VR) being a closed and controlled environment is often used for gamification and training. Whereas, if the interaction is along with the real world by augmenting virtual objects, then Mixed Reality (MR) can be used especially on Meta Quest 3 or Magic Leap headsets. However, Augmented Reality (AR) involves overlaying virtual elements in real world with restricted interactions.

This literature review restricts the scope to the articles identified and analysed whose studies are on designing an XR (AR, VR, MR, or a PC) application for testing loss of visual acuity and glaucoma with gamification techniques and designing low vision aids for users in XR. Accordingly, this study identifies, retrieves and reviews 59 research papers relevant to the scope of the study. The three Research Questions are framed for which the corresponding Research Gaps are presented that can help the researchers in the future for empirical studies in this field. In addition, this literature review can also be used by the XR designers and developers in understanding the design consideration to perceive an idea of prototyping an XR based visual function gamified tests.

II. BACKGROUND

Metaverse has been a key term when digital twin is discussed or gamification is included. As wearable computing is gaining popularity, the possibility of ubiquitous computing is feasible through having portable devices. The journey of the compact factor of the HMDs shows the compactness and portability of the devices through reducing the weight and size with tetherless in the recent VR/MR devices. However, along with Metaverse, the term Spatial Computing has also seen a boom in the recent past as a part of the Human-Computer Interaction (HCI) and Cognitive Computing which includes AR, VR, MR & XR.

Various attempts have been made to test the visual acuity and visual field in several devices ranging from a smartphone, PC [16] and a VR device [17], [18], [19], [20] to make it an automated digital test comparing with the conventional standards. Despite yielding satisfactory to good results, these studies lacked the design considerations to create a gamified visual function test and the base standards needed to be compared with the conventional testing. However, the potential for creating a gamified visual function test in XR is always increasing due to the better features of the newly released HMDs. Despite such devices being unfamiliar to the first time users, an improved user learning curve of device usage can be noted which showcases ease of use [21], [22]. The recent headsets like Meta Quest 3, Quest Pro (with eye tracker), Pico headsets have showcased the feasibility of having a cost-effective HMDs along with maintaining the portability through tetherless and having standalone processing capabilities. They also include MR and eye tracking along with the better Field of View (FoV) and Pixels-Per-Degrees (ppd). Having these features in one device along with its basic capability of 6DoF depth perception makes favourable of having a visual function testing environment virtually with the necessary testing standards and replicating the test environment at the user's comfort. This opens up a scope in creating a home based automated visual acuity testing and visual field testing with gamification to prevent boredom and motivate to have retest frequently. Moreover, this would not only reduce the fixation errors (in VF tests) or the detection to recognition threshold error (in VA tests) but also engages and makes the users feel comfortable unlike in the conventional testing. Few of the necessary background required in the scope of this literature review are segregated and discussed as follows:

A. VISUAL ACUITY

As visual acuity tests need a constant visual angle to be maintained throughout the test between the user and the optotype, the distance of the user from the optotype and the size of the optotype measurements should be accurate. To measure the distance in XR environments using 6DoF HMDs, few distance measurement interaction capabilities can be included in the testing virtual environment as shown in this work [23]. This enables the real to virtual world correlation of the test standards for better accuracy and comparison with the gold standards. This can be used to compute the real time visual angle and maintain the constancy throughout the test between the optotype and the HMD position in the virtual world.

B. VISUAL FIELD

Several works have been published where the visual field testing in various devices are conducted in order to showcase the portability of the testing device and various test

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(TITLE-ABS-KEY("EXTENDED REALITY" OR "MIXED REALITY"
OR "AUGMENTED REALITY" OR "VIRTUAL REALITY" OR "VR"
AND "VISUAL ACUITY") OR TITLE-ABS-KEY("EXTENDED
REALITY" OR "MIXED REALITY" OR "AUGMENTED REALITY" OR
"VIRTUAL REALITY" OR "VR" AND "VISUAL FIELD") OR
TITLE-ABS-KEY("VISUAL ACUITY" OR "VISUAL FIELD" OR
"PERIMETRY" AND "GAMIFICATION" OR "SERIOUS GAMES"))
AND PUBYEAR > 2015 AND PUBYEAR < 2024
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FIGURE 1. Search string utilized to identify the studies.

algorithms (Swedish Interactive Thresholding Algorithm (SITA), stimulus positions, transparency) [24], [25]. Studies have varied from creating an automated low cost perimetry device with controlled closed environment to creation of various types of perimetry like static, kinetic and oculokinetic perimetry in HMDs.

C. GAMIFICATION

Apart from the portability, the advantage of having a digitalised test is the automation. Various visual field algorithms (Staircase algorithm, SITA etc.,) and visual acuity testing charts (Snellen, Lea, logMAR etc.,) can be displayed based on the user's feedback or the test performance. Inclusion of level mechanism to motivate the user can be considered to induce challenge and motivation of retesting through competition of scores. These game mechanics can help the clinicians to determine the visual acuity and visual field thresholds of the participating user at the end of the test. The test duration usually lasts 10 minutes on an average based on the experiments in the studies included.

Despite the fact that some surveys and reviews are conducted on XR based visual function assessments, there are no literature that discussed the most recent design considerations for gamified XR based Visual Acuity and Visual Field testing using latest HMDs. The designers, content creators or the developers including researchers would have a great advantage in understanding this review while creating an XR based visual assessment gamified application.

III. METHODOLOGY

This literature review collects and integrates the studies that fall within the scope. This allows us to understand the quantity of works and the progress of the novelty of research in the selected field. The amount of available evidence and the quality of the works facilitates us to compare the different techniques and methods in the domain to assist us in determining the design considerations for Visual Field and Visual Acuity tests in XR and extending it for gamification. Accordingly, this literature review details and specifies the time frame of the selected studies.

A. RESEARCH QUESTIONS

The main goals of this study can be devised in the form of Research Questions (RQs). Following are the research questions framed based on the scope of our study:

RQ: What are the current trends in gamified visual function testing?

- **RQ1**: What are the design considerations and game mechanics used for visual function testing?
- **RQ2**: What is the accuracy obtained when compared to gold standards in visual function testing?
- **RQ3**: What are the devices used for the visual function testing?

To address the above research questions, the aim of the study is to develop a comprehensive understanding about the design considerations for XR visual function tests in the current state of the literature using recent HMDs. Based on these, a few research gaps are presented in the Section V.

B. SEARCH STRATEGY

The literature search was carried out in the month of November 2023 and resulted in 802 records from the Scopus database using the advanced search. The articles are searched based on their title, abstract, and keywords. The search query is shown in Fig. 1. Gray literature are also included in the study that consists of unpublished works, research reports, conference proceedings, blogs, preprints to be aware of the latest developmental scenario of the field that is upcoming. Few articles obtained from Google Scholar, PubMed, IEEEXplore, ACM are then populated into the final list of 59 articles. While retrieving the records from Scopus database, the publication year selected is from 2015 to 2024 which includes the uprising of the most common usable VR devices during the period. The review procedure is undertaken with the help of Microsoft Excel sheet where all the list of records are maintained. Zotero is used as the tool to organize the screened records and manage in a library based on the topic. The duplicate check and similarity checks are made by screening the excel sheet CSV document exported from the Scopus database, which is imported to the VOSViewer to generate the visualisation. The litmaps includes only the final list of documents included for this study but does not include the gray literature like webpage

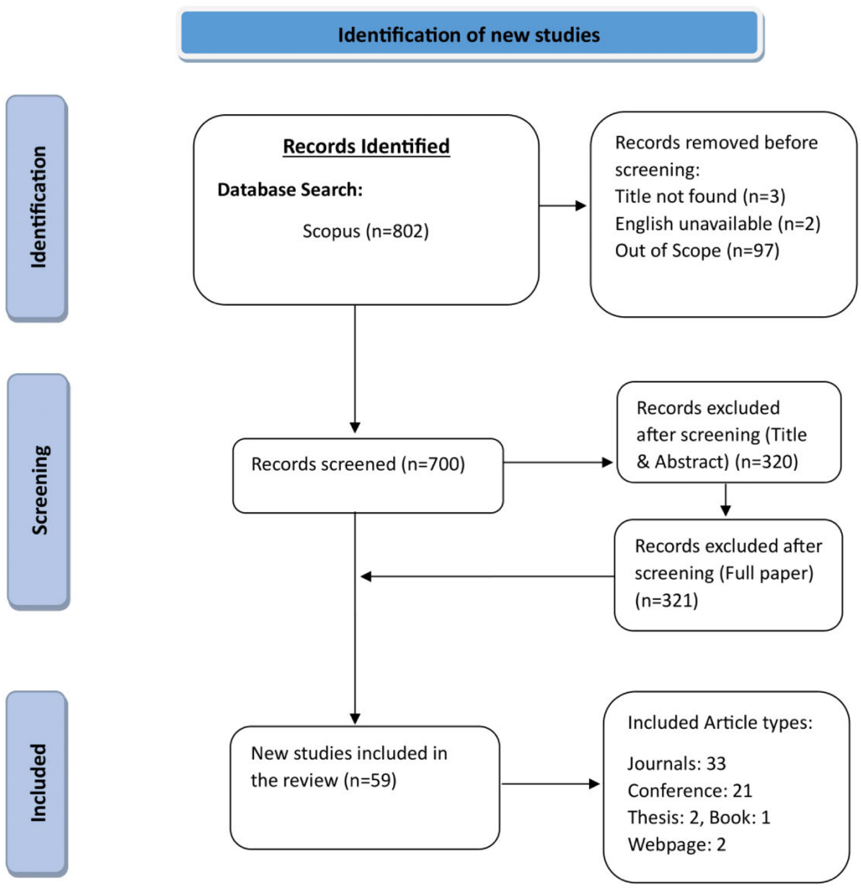

FIGURE 2. Process of shortlisting the studies from the Scopus database based on the Inclusion and Exclusion criteria and relevancy.

TABLE 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
I1 - Published between 2015 and 2024	E1 - Articles irretrievable
I2 - Identified by search queries	E2 - Articles not in English
I3 - Articles with relevant topic	E3 - Articles not having relevance to the scope
I4 - Articles with Novel ideas	E4 - Retracted publications

and thesis reports (n=4). Fig. 2 depicts the overall review process with the flow of selection of articles.

C. INCLUSION/EXCLUSION CRITERIA

The scope of this literature study is determined by specifying the inclusion and exclusion criteria. In order to address the research questions framed above, respective Inclusion Criteria and Exclusion Criteria are selected and are shown in Table 1.

D. DATA EXTRACTION AND SYNTHESIS

The major countries and the prominent authors who contributed to the selected research domain are visually represented through VOSViewer for the publications data obtained from Scopus database as shown in Fig. 3. Apart from this, the keywords (author keywords) interconnection and nodes are also represented through this software as shown in Fig. 4. The clusters are color coded and large circles represent more articles, thicker the line corresponds to stronger link and the distance between nodes indicate the relatedness. The network visualisations consists of 5 clusters (set of closely related nodes) with the nodes representing the author keywords having links to various other nodes. Node size represents the number of publications or frequency of occurrence of the keyword in the publication list. The position of the nodes also represents the relatedness between the nodes. The thickness of the links between the nodes signifies the strength between the nodes. For example, ''human'' and ''virtual reality'' keywords are related closely, hence placed nearer with many number of publications though belonging to other clusters. Visual Acuity and visual field are having two separate clusters. A strong link can be seen between ''virtual reality'', ''humans'', ''visual field'' and ''visual acuity'' keywords denoting the strength of these keywords in the publications from the list. However, a weak link can be seen between ''virtual reality'' and ''visual attention'', ''low vision'', ''video game'' showcasing lack of studies in

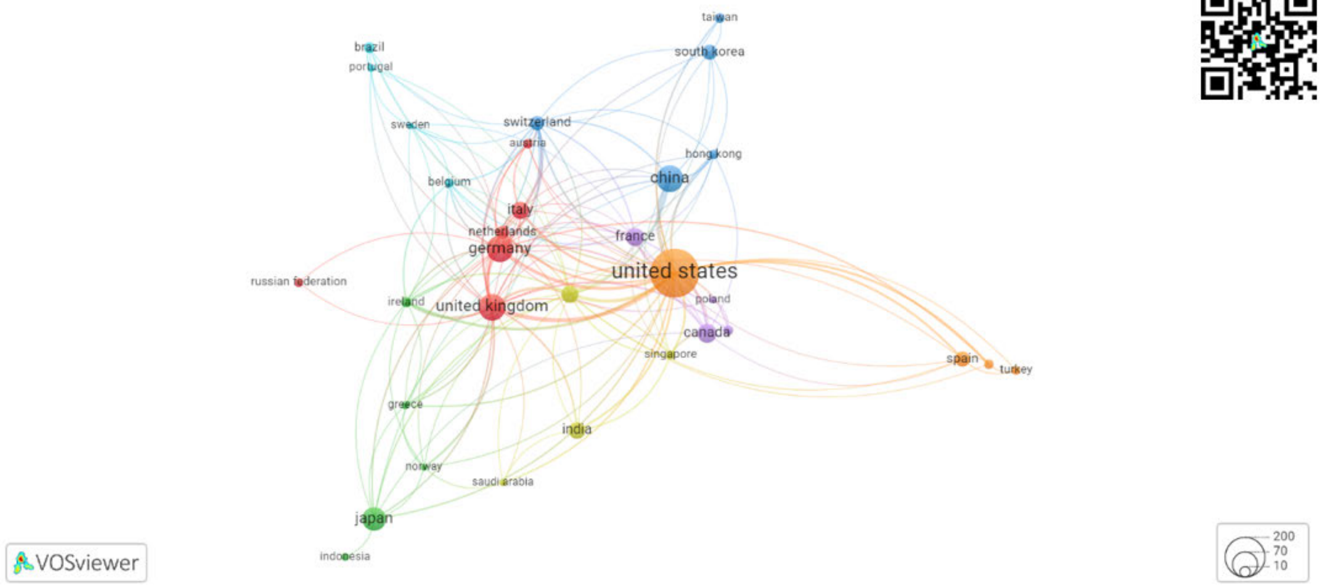

FIGURE 3. Bibliometric analysis visualisation of country co-authorship from the database search (Scan the QR Code for an interactive map).

the field. Based on the country wise studies analysis and determination, a good number of works have been carried out by authors from US, UK, Germany, China, Japan. Likewise, United States can be seen having a strong link with the UK authors in having publications in this selected area based on the search string (query). Though France have less number of articles, and a weak links with the US but are working in similar related fields as of the US. The final list of works are visually obtained through Litmaps on the basis of author who contributed in this research field as shown in Fig. 5.

The literature study allowed us to compare different methods, sample size, participant demographics. The primary aim of this review is to facilitate the design considerations required in designing a visual function testing virtual environment in either VR, MR or AR. It focuses on identifying the gaps and limitations of the current research work in the scope to provide guidance for future work.

E. META ANALYSIS

1) PUBLICATION BY RESEARCH AREA

To understand the selected research area publications and to gain comprehensive insight of the corpus of identified papers, Litmaps is used to construct an interactive literature map as shown in Fig. 5. This map includes circles (articles) of different size (citations) and are grouped (colored) based on the research area identified. Articles with similar titles are placed closely in the map. Upon examining this literature map, four prominent research areas came to the forefront as follows:

1) Gamification and Serious Games (represented in dark green and dark orange): The studies that included gamification of visual function assessments are found lesser when compared to studies using gamification for rehab or therapies like amblyopia, visual search, learning etc. Very few or no studies are found according to our knowledge which have used gamification for XR based visual function assessments.
2) Low Vision Aids (LVA) (represented in light green): These studies primarily focused on the development of vision aids for low vision people for using immersive technologies. Studies focused on creating and designing LVAs such as magnification, contrast enhancement etc., which involved vision impaired human subjects to evaluate the usability and effectiveness of the design in XR environments.
3) Visual Acuity (VA) (represented in light orange): Studies have utilised XR technologies as an innovative assistive technology to replicate the conventional chart based visual acuity tests mostly in VR which then is validated on the target population.
4) Visual Field (VF) (represented in lime yellow): This research area studies primarily involved in designing various kinds of perimetry and visual field testing algorithms on human participants and evaluated with the conventional testing standards for reliability.

2) PUBLICATION BY VENUE

Among the 59 articles identified, 33 resulted in journals and 21 are published & presented in conference proceedings. Remaining articles constitute the webpages, thesis etc., as gray literature. Among the publishers, articles retrieved from IEEE publications are the second highest number of articles selected in our review with Springer and ACM following. "Others" have constituted for a large number

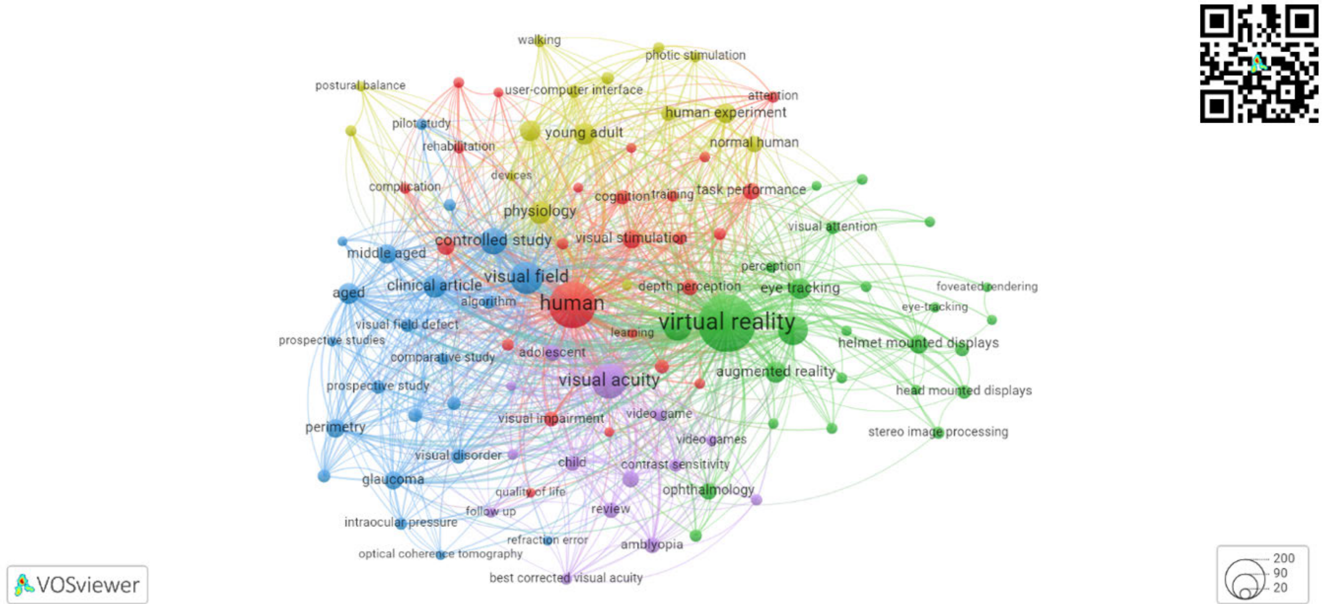

FIGURE 4. Network Visualisation of keywords co-occurrence from the database search (Scan the QR Code for an interactive map).

TABLE 2. Gender distribution of primary authors.

Gender	Primary	Total
Male	50 (85%)	50
Female	9 (15%)	9
Total	59	59

of portion in the selected list of articles as the area is interdisciplinary and various healthcare publishers have published the articles. The Fig. 6 shows a trend in the progress of the articles publishing in the selected domain of XR gamified visual function assessment as the year progresses. The years 2022 and 2023 have showcased lesser articles due to the unpublished work or research in progress in the concurrent period.

3) PUBLICATION BY AUTHOR

The selected 59 articles identified by our review process are written by many authors. Table 2 showcases the gender distributions of these article's primary (first) authors. Gender API is used to judge the gender based on the first name of the author. Approximately 85% of the first authors resulted in male.

Each circle denotes an article sized according to the citations and placed in ascending order (citations) from bottom to top, presented in a chronological order from left to right. (Studies selected are in total (n=55 without gray literature) segregated in terms of field of study: vf - Visual Field, va - Visual Acuity, lva - Low Vision Aids, sg - Serious Games) An interactive version of the map: https://app.litmaps.com/shared/01b3026e-7199-4048-94d9-6d5b36df43d6

Notable analyses can be inferred through the literature map: The VR low vision aids studies have received most number of citations along with visual field articles. This also represents the fewer number of publications and citations received for VR visual acuity studies, showing a scope for a deeper prospective research. Works in LVAs and visual acuity have been rising only in the recent times which may be due to lack of good resolution and quality HMDs before 2016.

IV. RESEARCH AREAS

This review categorizes and has identified the research works of VA, VF tests along with gamification and LVAs. The methodology, evaluation and results are the objectives to determine the study's strengths and weaknesses. An attempt to highlight the important design considerations for the development of more effective XR gamified eye related applications is made. As a result, we hope to see and derive a significant conclusion of the review regarding the optimal way of treating or testing an eye disorder through enjoyment. This review comprehends the mechanism of these techniques, compare their performance, and finally identify and address the research gaps in scope of the study.

A. XR VISUAL ACUITY

1) LOW COST VISUAL ACUITY TESTS

Many studies in visual acuity testing has been carried out in VR out of which few of the shortlisted study designed a low cost VR device for VA testing [33]. In another work, mobile VR cardboard is used where the IPD and the phone screen distance from the lens can be adjusted. However, the lens quality and magnification does affect the testing even if a high pixel per inch phone is used. The testing is carried

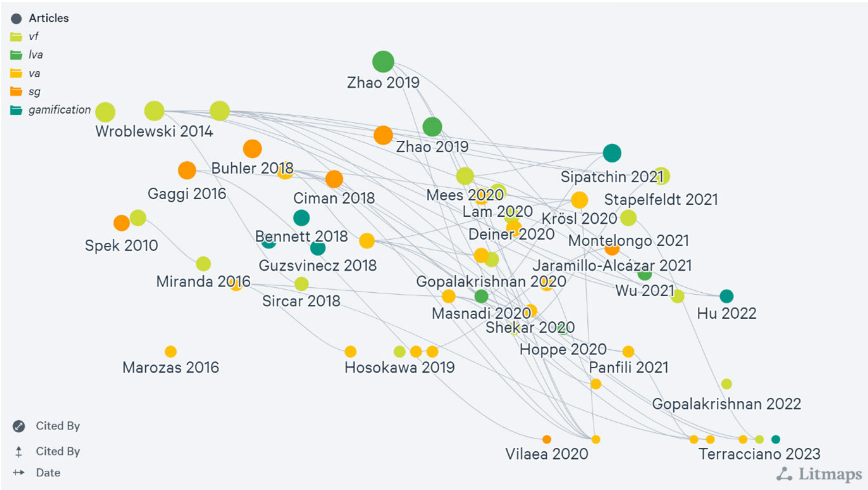

FIGURE 5. Literature map of the final list.

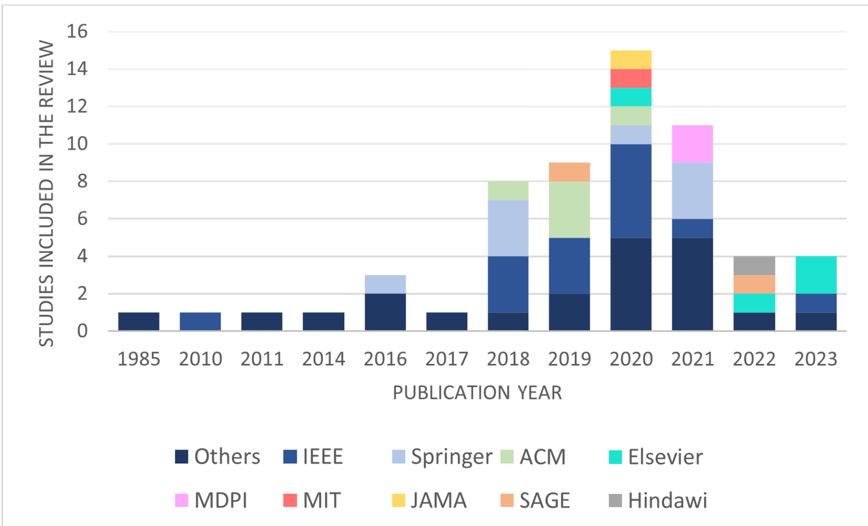

FIGURE 6. Year wise publication trend by the publishers in the final list arranged in increasing order based on the count.

out at 65 IPD value with monocular testing of one eye at a time by displaying black screen to the other. Participants did not wear any corrective devices while testing and Tumbling E is used as the main optotype whose size and orientation is changed based on the user's response [34]. The magnification and brightness (200 +/− 120 cd/m2) are considered and the author suggests having at least of 2560 × 1440 pixels to avoid blurred lines, uneven edges in the display. The designed cardboard has a focal length of f=50mm with Contrast between sight target (black) and background (white) 0.9 +/− 0.05 but no consideration of PPD. However, this test is a non-gamified version of the VA assessment.

2) ADVANCES IN RECENT VA TESTS USING LATEST HMDS IN XR

Adaptation of the text and font size and style for XR environments based on Snellen chart and Freiberg visual acuity test is discussed in [41]. The author discusses the design consideration of implementing a readable UI text in Unity for an XR environment. Along with the necessary optical calculations required for the optotype size and distance, the change in text color and font with background is possible by the user to test the optimal design for the readability in the corresponding XR environment.

Few works of testing visual acuity on the recent HMDs are being taken place of which one work [42] discusses of the perceived visual acuity and contrast sensitivity in a tethered 70ppd Vajro XR3 is measured and the HMD's perceived peripheral area's diminished resolution is also realised. Due to the better display capacity, the Vajro XR3 performed significantly better than Rift and Vive Pro. The test included displaying a series of wall mounted color symbols in horizontal and vertical orientation attributing to the checking of peripheral resolution. The HMD showcased a better

TABLE 3. Summary of literature review for types of visual acuity tests on various devices.

Paper	Methodology	Remarks
"Myopia in Head-Worn Virtual Reality, 2021 IEEE conference" [26]	Visual Acuity Measurement in VR using Landolt C and HTC Vive HMD.	Factors such as display resolution or vision capabilities of users influence the VA in VR, which needs to be addressed. Optotype Size and testing distance are not considered.
"Effects of VR-Displays on Visual Acuity, 2019" [27]	Optotypes used in the virtual environment is Landolt C with different orientation and user response adaptive size variation (in arcmins). HTC Vive Pro HMD is used with testing distance at 3m. Tested on 15 participants (10 nearsighted and 5 normal using both eyes) with 32 years average age. The test duration resulted in 10 mins. Results showcased the VA in VR is decreased than VA in non VR.	Optotype Size and distance are not validated with respect to real world.
"Characterizing Visual Acuity in the use of HMD, 2021" [28]	Four types of VA tests designed – Snellen, contrast sensitivity, two glare tests (peripheral and central) through shooting game mechanics. Rift CV1 is used with optotypes (stimulus) placed at 6m away from user. One eye is used at a time and tested on 23 participants with 20/80 to 20/100 acuity. Results found out that VA in VR is different than in real world.	Outdated HMD used and users found difficulty adjusting HMD in TLX and easiness of the study.
"Effects of Dark Mode Graphics on Visual Acuity and Fatigue with Virtual Reality Head-Mounted Displays, 2020" [29]	Visual Acuity Measurement in VR using Landolt C and Rift S VR HMD.	Optotype Size and testing distance is not taken into close consideration. Tethered HMD is used for testing. Need to know how can VR VA test be designed based on clinician advice.
"VREye: Exploring Human Visual Acuity Test Using Virtual Reality, 2020" [17]	Measured VA using VR with 20 metres virtual – real distance mapping. Snellen Chart was used for validation on 30 users (18-24 age) with 20/32 limited extreme value on Rift S with client-server architecture. Overall 50% accuracy was obtained.	The measurement of real to virtual distance mapping is unreliable as the headset used is wired. Size of the chart is not discussed, other types of acuity test is not considered, young children are not addressed hence need to understand how their attention is in a gamified visual acuity tests. Lacks design based on clinician advice. Need for evaluating and understanding how a design based on a usability evaluation performs for the VR visual acuity test.
"VR/AR Head-mounted Display System-based Measurement & Evaluation of Dynamic Visual Acuity, 2019" [30]	Dynamic Visual Acuity test King Devick-Saccadic test for saccadic movement analysis.	The tests are not clinician monitored. Implementing tests in real environment is significant for saccadic eye movement as shown in AHKD test in the study. Usability evaluation needs to be addressed elaborately.
"Pre-diagnostic of visual acuity through a serious game, 2020" [16]	LEA chart used to measure VA with 13 children. The test setup included varying symbol size, randomness, real time analysis. Gamification elements are considered with console interaction.	Kinect used for tracking head movement and constant distance from the PC screen; however, VR is optimal for the same. Average game completion time is calculated with only one linear regression model analysis. Different game levels with dynamic difficulty enhancement based on user performance are included. 85% of the users completed the full test.
"The use of games to help children eyes testing, 2016" [31]	Serious Games to test VA, daltonism in children through phone, wall projection, 65 children, 5-10 mins test. Used most of the VA charts. The findings shows that the Lea optotype are not suitable to assess children visual acuity equal to or greater than 6/10. Found out that when optotypes are small, the E or Snellen should be preferred.	Comparison of the effectiveness of the serious games test and their enjoyability/attention for standardization of home based diagnoses. Considered Likert scale analysis only. Need to understand how would VR VA test design play a role when compared to this design.
"Simulating cataracts in virtual reality, 2021" [32]	Testing distance is kept above 1m and till 6m for shortsighted users. Landolt C of size approx. 1.75mm at 6m distance should be recognized by 6/6 user. The respective viewing angle corresponds to 1 arcmin (1/60 of a degree).	Hardware considerations and vision capabilities are not taken into consideration.

TABLE 4. Summary of literature review for advances in visual acuity tests using latest HMDs in XR.

Paper	Device	Optotype	Limitations
"Evaluating the Applicability of Repurposed Entertainment Virtual Reality Devices for Military Training, 2018" [35]	VR HMDs used are Vive, Rift. Pixel density, distance and size of stimuli are considered in the test scenario using Military equipments of real-world size 0.85m at 25m testing distance for which 16 pixels are used. However, results showcased difficulty for users to determine the virtual object.	Snellen chart of 1m x 1m (Topmost "E" 88.6mm) @ 6m testing distance is used. Results achieved 20/40 in Rift (min. 2100 ppi) and 20/50 in Vive (min. 2700ppi but 447ppi is used).	No consideration of optical distortion by the lens. The study found out high pixel density is of no use unless lens quality is good and concludes that Rift is not recommended for visual acuity testing.
"Characterization of Visual Acuity and Contrast Sensitivity using Head-Mounted Displays in a Virtual Environment: A Pilot Study, 2019" [36]	VR HMDs used are HTC Vive Pro and Oculus Rift.	The experiment setup involved Laser scanned 7 x 7 ft room with Landolt C placed @3m and Snellen chart @2.8m. Results of visual acuity yielded Avg. of 20/100.	Lens magnification, chart size and focal distance are not considered or discussed.
"Characterizing Visual Acuity in the Use of Head Mounted Displays, 2021" [28]	VR HMDs used is Rift which has 40mm focal length [37]. To avoid Screen door effect, smaller pixel size but high PPD and FoV with resolution of 9600 x 9600/eye is to be considered to achieve 20/20 for 60 PPD at 150 FoV, which is normal human eye.	The test scenario involves Snellen chart placed @ 6m testing distance with 0.5 arcminutes. Monocular and binocular vision to be used during Shooting test game. Results achieved are 20/80 (using both eyes for 11 participants) and 20/100 (using left eyes for 9 participants).	HMD needs to be adjusted correctly to the users to tackle Inter Pupillary Distance and glare issues. Also emphasizes on lighting considerations in virtual environment which is lacking in this work.
"Multimodal assessment of visual function and ocular structure for monitoring Spaceflight Associated Neuro-Ocular Syndrome, 2022" [38], [39]	Combining visual field, visual acuity and other visual tests in portable VR for SANS diagnosis of astronauts in Space missions. Staircase method was used for VA test standards with Landolt C as optotype stimulus.	Near VA tested with distance @ 34cm like newspapers. Distance VA tested for distance @ 3m like signs, texts.	HTC Vive HMD used which has 13ppd but 60ppd is minimum for VA testing with full potential. Not many samples tested on.
"Identification of visual functional thresholds for immersion assessment in virtual reality, 2020" [40]	VR HMDs used is Vive Pro with a resolution of 2880x1600 and 4.6 arcmin and designed a gamified VA test.	Functional threshold (measured by decreasing) resulted in 96.6 degrees for FoV and 12.2 arcmin for VA (30 participants of 22-63 years wearing glasses).	Validation of resolution to arcmin conversion is necessary.

peripheral resolution among other HMDs. 14 participants of varying eye power took tests with corrective lenses on (30 mins). Though the Snellen charts, Landolt and contrast sensitivity charts are kept at a measured 9ft/10ft distance, the depth perception tests are not considered. Various symbols of different colors at specified FoV in a four quadrant at 6 feet is used to test the peripheral vision. Similar to the work in [36], the test environment is taken a 3D scan after it is setup. Vision charts are rendered in the virtual environment (VE) with the real world dimensions and distances. The scan is done through point cloud and rendered to design the virtual environment.

B. XR VISUAL FIELD

1) LOW COST PERIMETRY AND ADVANCES IN VF TESTS

Many studies for VF Tests using XR have been designed who have tried to overcome the problem of the conventional perimetry of long fixation time in an uncomfortable position and gamifying them [14], [49]. One of such work shows through a virtual bank scenario in VR regarding how low vision people with central and peripheral field loss achieve task and in what time [50]. This is conducted through a mixed method study using CV1. Five Participants in each 3 groups had to read sign board away from 3m which varied in font size by examiner. Contrast, visual search, visual angles are few visual parameters measured along with the time taken to complete the bank tasks. This work has not considered the aspect of pixelation, resolution and no visual field assessment. The work showcased a significantly worst performance in low vision people than in normal. The peripheral field loss people performed task completion much slower and used more time to complete tasks [51]. Besides this, another notable work where Oculus Quest 2 is used to measure visual field by kinetic perimetry

TABLE 5. **Summary of literature review for types of visual field tests in various devices.**

Paper	Methodology	Remarks
"Visual field examination method using virtual reality glasses compared with the Humphrey perimeter, 2017" [43]	Automated Static perimetry test to determine VF using VR. Showcased high correlation to Humphrey Visual Field Analyzer (HFA).	However, this is not a cross platform application that works in any VR HMDs. Static perimetry requires pupil diameter and eye movements, but these were not recorded during examination due to unsupported VR device used. In addition, difficulty to fixate for children for long duration is observed.
"GearVision: Smartphone Based Head Mounted Perimeter For Detection Of VF Defects, 2018" [44]	Home based perimetry using portable and cost efficient GearVR HMD. Participants tested were in the range of 21-45 years age.	A static perimetry that works only using obsolete Gear VR device. The test is not targeted for young children population.
"Use of Virtual Reality Simulation to Identify Vision-Related Disability in Patients With Glaucoma, 2020" [45]	VF assessing in day & night time in city using stair navigation virtual environment. Findings suggested the visual related disabilities depends on lighting and task condition in glaucoma patients.	Used HTC Vive – Navigation with this tethered headset is not addressed. However, VR provides a new perspective for clinicians to understand the patients' visual impairment.
"A novel paediatric game-based visual-fields assessor, 2011" [46]	Central fixation and peripheral target games played on a 2D computer screen using a button to analyse the visual field of the patient.	There is a need to know how to design a VR VF test for the paediatric population. Also, needs research on how can gamification principles and attention seeking in VR be designed for such tests.
"Development of a paediatric visual field test, 2016" [47]	Gamified eye test for pediatric population on a computer setup. Visual field testing on a 2D screen is carried out. The test was carried out on 14 subjects and showcased feasibility in designing game based VF test for paediatric use.	VR HMDs devices maybe optimal due to its immersive nature and wide FoV with novel interaction elements for game based test environments.
"Gamified vision test system for daily self-check, 2019" [18]	This work consists of a set of video games for quick, self-eye tests (approx. 3 minutes test duration). VF static perimetry test with paradigm of C-20 pattern in FDT included gamified elements which resulted to be enjoyable.	Smartphone based browser app tested in bright room for 13 participants resulting in 94% VF test accuracy. However, need to consider low vision participants for testing. Lacks clinician advice during the design of this test scenario.
Visuall, Optics Trainer, Olleyes - "A Virtual Reality-Based Automated Perimeter, Device, and Pilot Study, 2021" [12], [15]	Gamified eye tests and treatments using various non commercial VR devices designed by themselves.	Unavailable as an open source application. There is an urge in determining how can the usability evaluation of such gamified tests affect patients VR testing experience.
"Validation of a Head-mounted Virtual Reality Visual Field Screening Device, 2020" [48]	C3 Field Analyser (CFA) perimetry with 54 stimulus position that includes SITA HFA algorithm. The experiment included 157 participants (control & glaucoma). HFA tests were deemed unreliable if the false positive (FP) or false negative (FN) rate was > 33%. Tested on Desktop and VR devices. Results shows CFA correlates to HFA with mean deviation (r=0.62,P<0.001), pattern SD (r = 0.36,P<0.001).	Did not reliably identify deficits that matched HFA, but moderately effective to identify glaucoma patients. Distortions were observed as visual field were captured on a flat screen.

following Goldmann kinetic perimetry approach have found positive correlation with Humphrey visual field analyser through Pearson correlation. 21 healthy subjects (5 males and 16 females, age range 22-73 years) for a total of 42 eyes are tested. This work shows a portable and more accessible way of testing visual fields. The device gives control through controller for feedback when stimulus is presented. Unity is used for stimulus to move in vectors. Sensitivity threshold is achieved by moving different targets along vectors from non seeing to seeing [24].

2) OCULOKINETIC PERIMETRY

Few of the Oculokinetic perimetry in VR have been used as a home based perimetry testing device as an alternate to conventional tests [25], [52]. This type of perimetry does not need the user to fixate on the fixation target continuously throughout the test, removing the sense of discomfort. This uses the patient's foveation refluxing in order to detect the VF. One of a work which shows a Home based testing device with 10 tests in 14 days (to lower test-retest variability), each location in 24-2 grid tested 4 times/test. This work showcased correlation with Humphrey field analyser but the Oculus Go with less FoV is used limiting the test values extremity [53].

C. XR LOW VISION AIDS AND GAMIFICATION

1) SERIOUS GAMES

Inducing game elements into a serious context and making it enjoyable is considered to be gamification where as Serious games are designed on a purpose other than entertainment. Many studies have undertaken in inducing serious games to enhance the attention in the users. One of which is using various auditory cues [65]. Few other have designed serious games for treating people with dyslexia using various cues through a puzzle game to target certain cognitive areas [66]. However, such cues and gaming elements can also be added in VF, VA testing for the required benefits [67], [68], [69]. Eye tracking HMDs can be the key devices that can be used in the near future for a high fidelity gamified accurate visual function tests with real time eye movement analysis [70].

2) LOW VISION AIDS

Low Vision aids in XR can be designed for playing in XR for testing visual functions more likely when VR is common in future. LVAs can also be designed to help visual impaired people in real life by providing visual aid in terms of navigating or enhancing the visual acuity [71]. Few works on simulating vision impairment, especially cataracts using XR technologies is discussed in [72], [73], and [74] to understand the vision impaired people's problems in different perspectives. This enables in using the depth perception to simulate the viewing of the environment similar to people with cataracts.

V. DISCUSSION

A. VISUAL ACUITY AND SERIOUS GAMES

Visual Acuity testing studies in VR have been ranging from static to dynamic visual acuity [30], [75]. Few works have tried experimenting Visual Acuity test of the participant in few VR devices with game elements. One of a work used a tethered Oculus Rift S [17] which used Snellen chart with 30 participants and found values to be correlated to few participant groups with that to the conventional VA tests. The environment included signifiers and real-virtual distance mapping but did not discuss on the size, angle of the optotypes. The minimum age of participants was 18 and is not gamified test, hence not tested on children. We have come across few other articles who have tried to simulate VA testing condition in various VR devices with various VA tests and found a good correlation with the conventional tests but were not gamified and tested on children [29], [58], [71]. In addition to this we also explored several visual acuity test experiments in various other test setup environment of non-VR with few tests on monitor, few other on smartphones for children with gamification and showcased serious game can dramatically reduce the length of the tests [16], [31].

B. VISUAL FIELD

There have been various attempts made by many research articles to have an alternative to the conventional visual field testing. Based on the VR specifications, many visual field-testing experiments have been proposed of which most are replicating the capabilities of an automated perimetry [76], [77], [78]. Most of the tests are static perimetry tests that correlates with the conventional standards and has the potential to replicate the test standards [43], [48]. In [15] the author has developed a static perimetry test on a Pico powered HMD VR device solely meant for testing eye. Various testing protocols like stimuli size, position, thresholding algorithm, fixation loss strategy, False negative, False positives etc., have been considered in the study. The results showcased most of the 6 participants' values correlated to the conventional tests and showcases VR to be an alternative for visual field testing, though not exactly accurate. A few works have discussed creating visual field tests for paediatric population on a computer setup [46], [47]. With all the above discussed tests, we observe that there is a need for the participant to fixate the head and eye at the fixation target and click the button whenever they see stimulus blinking with their peripheral vision. The problem of fixating as in static and kinetic perimetry can overcome by using oculo-kinetic perimetry technique where the appeared stimulus every time acts as the fixation target so that the user would have to move their head to fixate which have been shown in [53] and [77]. These works also have a very good test-retest reliability with positive correlation to HFA. Apart from this, the doctors can monitor and control the test environment in real time.

The necessary gamma corrections of the display screen of the device must be noted for the transparency of the stimulus in the virtual world. The appearance, spawn location, position and size of the stimulus needs to be taken care in visual field testing perimetry environment. Static perimetry involves the user fixating on the fixation target throughout the test when the stimulus of corresponding test standard is displayed in the peripheral FoV for which the user has to respond for every stimuli seen. The response can be through the HMD controllers or voice. In spite of having a HMD, this test scenario would work only for an eye tracking HMD that tracks the saccades, fixation, gaze of the eye in real time in the virtual world. FoV can be gradually increased by displaying the stimulus away from the fixation target at the central visual field. The distance to FoV relation needs to be studied to position the stimulus in the virtual environment. However, few HMDs have restricted field of view of approximately 100 degrees horizontally and vertically.

C. SERIOUS GAMES AND GAMIFICATION

The author in [79] discusses an overview of serious games which has been exponentially growing in the last decade. A special attention needs to be considered while designing and developing serious games for which the author has drawn guidelines from literature: Adaptive gaming, social

TABLE 6. Summary of literature review for LVAs in XR along with VA, VF tests in various devices with serious games.

Paper	Methodology	Remarks
"SeeingVR: A Set of Tools to Make Virtual Reality More Accessible to People with Low Vision, 2019" [54]	Low vision aids tools design for the usage in virtual environments for any HMDs. There are 14 LVA tools designed and tested on 10 games.	These LVAs are not tested on Serious Games and lacks heuristic evaluation to understand if it affects user experience and engagement.
"CLEVR: A Customizable Interactive Learning Environment for Users with Low Vision in Virtual Reality, 2020" [55]	Radial menu addresses visual, acoustic and haptic senses to ensure usability and access to PC screen in virtual environments using VR.	A tethered HMD HTC Vive is used in the test setup. However, this is not tested on Serious Games. Embodiment, presence and engagement are not assessed. Lacks Navigation and Multi user virtual environments LVAs.
"VRiAssist: An Eye-Tracked Virtual Reality Low Vision Assistance Tool, 2020" [56]	Dynamic eye tracked distortion correction, magnification, color enhancement, image remapping are the various LVAs designed for VR.	Lacks VR interactions, navigation LVAs and glaucoma patients are not considered. Used on VR image, LVA for dynamic scene is not tested on.
"Towards accessible news reading design in virtual reality for low vision, 2021" [57]	Proposes the design of Tool box and browser based LVAs. Page layout, color inversion and accessibility menu in view space is discussed. Not tested on participants as only prototype design is discussed.	Displays of HMDs affects the reading in virtual environments. Low Refresh rate would affect the VR experience which is not analyzed. There is a lack in studies to know how would the LVA tool affect in learning, driving in terms of saccades, fixators and identify if user has seen the sign board or not as discussed in the work [58].
"Designing AR Visualizations to Facilitate Stair Navigation for People with Low Vision, 2019" [59]	LVA – visualization & sonification for Projection based & smart glass AR. Heavy AR glasses device with small FoV.	Real-world situation and crowdness of people was not considered. Usability is not evaluated as the AR signs may not be visible in daytime.
"Virtual Showdown: An Accessible Virtual Reality Game with Scaffolds for Youth with Visual Impairments, 2019" [60]	Vibration, verbal scaffolds are used as LVAs. Determine the ball position in the virtual environment by 3D sound. Results shows most were engaged and liked the LVAs.	Test setup included Kinect and not a VR HMD. Audio and haptic scaffolds are available only for one object as precise location of the ball is not addressed with this cue.
"Serious Games to Support Cognitive Development in Children with Cerebral Visual Impairment, 2018" [61]	Proposed activities are played with two-fold goal which is to assess the level of processing of the visual information available to them, and to analyze the learning potential and retention of visual information. Games played on computer screen including eye tracker with remote clinician monitoring.	There is a keen interest on if VR can implement such tasks for converting gamification to visuo-motor coordination and visual attention. Also needs to research on if it is possible for visual object recognition through VR in peripheral field for visuo-semantic decision-making skills.
"A VR based user study on the effects of vision impairments on recognition distances of escape route signs in buildings, 2019" [58]	Simulated low vision environment is designed and tested on HTC Vive with healthy participants and Landolt C as stimulus.	Blurring an image is made until the recognizable threshold is found. Tetherless HMD should be considered for better analysis of navigation.
"Reducing VR Sickness through peripheral visual effects, 2018" [62]	No reduction in FoV while navigating. The 18 test participants indicated that reducing optical flow in peripheral vision is promising to reduce VR sickness.	Need to be tested on gaming elements and vision assessments in the virtual environment.
"Virtual Reality Based Assessment of Static Object Visual Search in Ocular Compared to Cerebral Visual Impairment, 2018" [63]	The experiment setup included VR with no HMD. Cerebral and Ocular visual impaired children and adults found difficult performing the task of locating and identifying a toy when it is in close proximity to other toys, but can locate the same easily in isolation. Participants viewed a toy box from an overhead perspective to simulate looking down into the box. Devices used are Tobii eye tracker and leap motion for visuomotor coordination.	The analysis and comparison of this task performance with HMD would be interesting. Similar gamified visual function testing environment needs to be designed and evaluated in VR with depth perception as in real world.
"Assessing Visual Search Performance in Ocular Compared to Cerebral Visual Impairment Using a Virtual Reality Simulation of Human Dynamic Movement, 2018" [64]	The assessment scenario involves use of heatmaps of eye gaze fixation and saccades using Tobii eye tracker. Overall, individuals with Cerebral visual impairment took longer to find the target than both control and ocular visual impaired participants when task difficulty was highest.	Through naturalistic and realistic virtual environments, the assessment of search performance was found to be optimal. However HMD is not used but used only a monitor with an external eye tracker on 35 users. Required to undertake the similar testing environment in 3D VR Environment and analyse the performance.

well-being, multimodal Serious Games, User centred software engineering, standardization of evaluation and sensory based simulations. The author suggests the designers to maintain a balance of the primary reason and the entertainment components while designing Serious games. Apart from this, serious games have been applied in the field of healthcare of which one of a work is related to visual treatment on a few devices as shown by [61] which includes visual decision making & learning potential and visuo-motor coordination tasks in children to support cognitive development. In [12] the work proposes a pre-diagnostic VA test through serious game on a 2D screen with Kinect tracking the distance between the head and the screen. With these serious games, we learn that the user has enjoyed taking the tests which might increase the accuracy. There is a keen need for a solution and to research on how VR gamification can improve the test accuracy, experience in the user. Some VR products which are completely meant only for vision test have been extended by other base VR headsets, out of which Olleyes, Vivid Vision are among them. They provide gamified tests for various vision treatment like lazy eye, strabismus, glaucoma etc., and need to be more looked upon research prospective for gamification of VF, VA test in VR [12], [14].

D. LEARNING OUTCOMES OF MAPPING GAME MECHANICS TO VISUAL FUNCTION ASSESSMENT

From the above discussions, relevant game mechanics can be induced in the testing scenario (based on game mechanics and stimulus similarities) of the virtual environment that make use of the HMD and its features like 6DoF, depth, FoV, eye tracking, controller, haptics. The test algorithm can adapt to the user testing performance and procedurally generate accordingly the difficulty of the test scenario. Haptic, visual and audio feedback can be given for every action performed along with the level mechanism and test standards and algorithms. Scoring system can be adapted for loss of fixation or presence of false positives and false negatives especially in the VF testing and guessing threshold for a certain size/distance in VA testing. Hand tracking can be used if necessary and relevant. The combination of embodiment and storytelling can immerse the user and engage in the testing [80]. Designers should make sure the application includes the affordances and usability in designing the XR environment and focus on the visual impaired people as target users to avoid nausea and steep learning curve. Low Vision Aids can be added as an optional feature for the target users with more than one vision impairment to be used while testing the other. HMDs can render binocularly or monocularly on the displays, hence with the guidance of the optometrists the target audience and the test scenario can be decided before developing the XR gamified visual function assessment prototype. The real time testing of the participants can be monitored remotely from the clinician and control the test elements through server-based application. The possibility of generating a report of the visual field loss or the participant test performance in the VA/VF tests can be shared to the clinicians at the end of the tests.

E. INFERENCE DRAWN TOWARDS RQ1

Most of the researchers have focused on using a light weighted HMD and a standalone portable device for automated self-testing. Few researchers have come up with their own HMD and others have designed an HMD specific application. Table 3,4 show the gaps and the limitations of the research where the optotype size and the visual acuity testing principles are given less consideration in most of the studies while designing an XR application. Moreover, gamification in HMD is not designed for a visual acuity test application. However, visual field testing studies includes the game mechanics in the design along with the emphasis on testing characteristics (see Table 5). Despite this, few gaps and limitations such as lack of clinicians' advice while designing and lack of real time clinician monitoring are noted. Regarding the game mechanics, there is a lack in fidelity of the gamification involved while testing and needs clinicians' advice in choosing the game scenario & stimulus characteristics to check if it would affect the testing environment. Advanced game mechanics having naturalistic interactions would enhance participant engagement such as shooting, bow & arrow and slicing techniques. Adaptive difficulty and scoring system can also be included to induce the motivation in the users. A gamified XR based visual field application is lacking in the research market for a better engagement and testing scenario. There are a few research articles who have designed Low vision aids for VR or AR environment to low vision impaired people so that they experience VR in a better way or use it as a visual aid in the real world, respectively (see Table 6). The authors try to address and provide LVAs ranging from VR image to dynamic VR scene with techniques like contrast enhancement, magnifiers, image remapping in various VR environment condition like reading, VR classroom, or providing LVAs as a toolkit to be used in other VR games and apps [54], [55], [57]. However, these are affected by the HMD used depending on its FoV, resolution, portability, controllers etc. By analysing these works we notice that the usability of such LVA is not discussed along with how users would feel embodied while using LVA. A need to analyse the users' Sense of Embodiment (SoE) and presence in the virtual environment with various VR/AR LVAs is required. Finally, all the results that has been obtained and analysed needs to be compared with other VA & VF tests and LVAs on various other devices including VR to test the optimality.

F. INFERENCE DRAWN TOWARDS RQ2

Though the accuracies of the participants recruited (avg. sample size n=30) have shown a good correlation in the studies reviewed, there are various ways in enhancing the design considerations that are needed to achieve better VA and VF test scenarios and results in XR. The VA tests should consider involving the size and the distance measurement along with the visual angle measure in real time in the virtual world. The usage of Vector graphics instead of sprites or 2D textures can make the optotype display more clearly especially reducing the jaggy or shimmering sparkly effects by aliasing. Usage of Vector graphics for optotype design can reduce the differences in recognition and detection threshold and avoid users to guess the optotypes during testing. The distance of the user to stimulus and the FoV relation must be mapped while designing the VF tests in the virtual environment to know the extremities of the stimulus placement. However, the results would depend mostly on how the HMD is placed on the user's face. As various display and optical limitations are possible like god rays, absence of sweet spot, chromatic aberration etc., there is a need to make the user see the virtual environment clearly through the HMD. Later, the noting down of the test results also has to be consistent in determining the threshold, especially when comparing conventional with VR tests.

G. INFERENCE DRAWN TOWARDS RQ3

The studies included devices ranging from smartphone, PC, various HMDs such as HTC Vive, Samsung Gear, Google Cardboard, Quest, Rift. However, the usability study needs to be considered for the design application and the HMD used by the target audience to realize the comfortability and engagement of the test. Eye tracking and HMD display & rendering consideration in XR studies are lacking for VF and VA tests which play a huge role in analysing the results of the test and affecting the accuracy. Due to the rise of the portability and processing power in the HMDs, especially as seen from Oculus Rift to Meta Quest 3, the inclusion of the eye tracking features and the retinal resolution in a cost-efficient portable headset would be soon available for the customer release in the XR industry. This showcases the potential of designing the gamified visual assessment applications for XR devices.

H. OVERALL INFERENCES

Due to the rapid increase in the number of visually impaired people in the recent days and due to the lack of clinician's availability in a pandemic situation, there is a need to find an alternative for the vision tests as they need frequent close monitoring of the progression of their visual acuity and visual field. Due to the advantages and optimality of the XR capabilities to simulate such tests in XR and have constant real time monitoring for the clinician, there is a prospect to implement such research. Several research articles have shown the efficacy of such similar works earlier and have found positive correlation of the accuracy with the conventional tests as shown in Section III.

As there are various disadvantages of standard perimetry test, like high cost, lengthy uncomfortable tests and boring conventional tests lacking motivation this review can lay a strong base for designing a suitable alternative. Though the visual function assessments should address all age categories, there is a need to enhance the testing experience and motivate the participants to have frequent regular tests, to increase the accuracy. The gamification of the test environment possibly increases the attention especially in children. Also, the age specific game mechanics needs to be considered in the design. As VR is expanding rapidly and has been used in various rehab, serious games, and treatment techniques there is a need to design LVAs for people with Low Vision impairments and evaluate it. By designing LVA, researchers can have a possibility to validate the developed tests for different levels of visual impairments. Finally, there must be a suitable comparison of the developed tests with the gold standards and on other devices to find an effective test based on the scenario and understand the vision impaired individuals' problems in a different perspective.

I. RESEARCH GAPS AND KEY TAKEAWAYS

Based on the literature maps and network visualisation, we observed that there is a lack of works in the gamifying of visual acuity test in XR and understanding the game mechanics relation with the participant engagement and attention. However based on the literature, we infer that there is a lack of study on:

- Gamification of visual acuity tests and visual field tests with iterative design approach of having the testing on target audience and the clinician advice for every prototype designed [16], [31].
- Distance mapping in virtual world to real world [17], [26], [29].
- Consideration of Visual acuity test criteria like visual angle, size of the optotype and device display & rendering consideration like Vector graphics, brightness & gamma correction of the screen [17], [29], [30].
- Mapping of game mechanics to the stimulus of the visual acuity and visual field tests - consideration of the background and optotype colors and mapping the interactions, test environment [44], [61].
- Distance to FoV considerations and relations for peripheral field testing - How far the stimulus should be visible for a very short period along with the fixation target [15], [43], [46].
- Selection of age based engaging attention and motivation inducing game mechanics and using optimal device for testing based on usability score [15], [30], [45].
- Lack of discussion on how clinicians can constantly monitor VF tests and change the parameters for VR tests [15], [43], [44], [46].
- Pixel per Degree to Arcminute mapping for the optotype design should be considered [17], [29], [30].
- LVAs usability testing for embodied characters in virtual environment is lacking [54], [55], [56].
- Usage of Eye Tracking to yield accurate results especially in static perimetry VF tests is not performed. Heatmaps of the real time eye fixators and saccades of the users can yield an efficient analysis for the clinicians in XR based VA VF gamified testing [16], [17], [31].

VI. CONCLUSION

By synthesizing and analysing the recent literature of 59 published articles, several important findings for the current state of the XR gamified visual function testing (devices used, research methodology) were observed. The same may be useful for the researchers to leverage this field of study to make this as a substitute for the conventional testing. This study not only provides key insights on the design consideration of game mechanics and visual function testing in XR but also conceptualizes XR as a portable technology for substituting the real-world testing at the clinics. By addressing three proposed research questions, we hope that a valuable contribution has been made through this study especially for the VR content creators and developers who may design the application in the future.

To ensure the review quality, this study took the rigor and the relevance of the review into main consideration. There may have been a few publications missed for which the future studies may include the usage of EBSCO, Web of Science, JSTOR etc., databases. This review also considered the inclusion of only English language articles which further limits the scope of the articles considered for this study. Finally, this study considered the visual function testing of visual field and visual acuity only along with gamification and low vision aids design. Upcoming works can consider other additional visual functions testing like contrast sensitivity, depth perception to expand the design understanding and feasibility of spatial computing in visual testing scenarios.

DECLARATIONS

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