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ORIGINAL RESEARCH

Novel Glasses-Free Distance Stereotest Using Eye Tracking: Evaluation of Sensitivity, Validity, Reliability, and Monocular Cue Masking

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Objective: This study assessed the sensitivity, validity, reliability, and monocular cue masking of a novel glasses-free distance random-dot stereotest system (GFDRDSS) compared with the established Distance Randot stereotest in youth with normal vision.

Methods: A total of 185 participants (17–20 years) with normal uncorrected visual acuity and eye alignment were enrolled. Distance stereoacuity was measured by GFDRDSS at 5 m and Distance Randot at 3 m. Among 38 participants, stereoacuity was measured under normal and induced monocular blur conditions using Bangerter filters for blurring. Test-retest data were gathered from 58 additional participants. Thirty-eight normal participants were tested with both methods to compare the sensitivity of the two stereopsis acuity tests. The same 38 participants had their monocular vision blurred to suppress stereopsis, followed by testing with the two methods mentioned above to evaluate their effectiveness. Additionally, 58 participants underwent repeated testing with a one-day interval to compare the stability of both methods, 89 participants used one eye to identify stereograms in revised GFDRDSS, GFDRDSS, and DR, and compared the monocular cues present in the three methods.

Results: Among the 38 participants, 81.58% achieved 60 arcsec stereoacuity with GFDRDSS and 100% reached 100 arcsec, while 47.37% achieved 60 arcsec and 97.37% 100 arcsec with Distance Randot ($P = 0.58\times10^{-3}$). With monocular blur, stereoacuity in 89.47% (34/38) of participants fell to ≥ 200 arcsec with both stereotests ($P = 0.115$). Test-retest data indicated identical stereoacuity in 70.69% (41/58) of participants for GFDRDSS and 79.31% (46/58) for Distance Randot. Using both GFDRDSS and Distance Randot tests, 5.62% (5/89) of the participants were able to correctly perceive stereoscopic images with a disparity of ≤200 arcsec using only one eye. Under revised GFDRDSS conditions, only one participant was able to correctly perceive stereoscopic images at the 800 arcsec level using only one eye.

Conclusion: GFDRDSS demonstrates greater sensitivity and comparable validity and reliability to the Distance Randot stereotest. Improving the design of stereoscopic random-dot patterns can effectively eliminate monocular cues, supporting its potential in clinical stereotesting.

Keywords: autostereoscopic display, eye tracking, random dot stereogram, stereoacuity, stereotest

Introduction

Stereoscopic vision is the ability of the visual cortex to extract binocular disparity information from the two-dimensional images received from each eye and synchronize them, enabling the perception of a single three-dimensional image with

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depth information. It is an important tool for evaluating depth and distance and serves as a crucial prerequisite for hand-eye coordination. Any condition that causes abnormal, unbalanced, or uncoordinated eye positions between the two eyes will result in stereoscopic vision dysfunction. Therefore, stereoscopic vision evaluation methods can be used for occupational screening in jobs that require fine binocular vision, such as drivers, athletes, microsurgeons, and they also aid in the assessment and efficacy determination of conditions like strabismus, amblyopia, and refractive errors. Distance stereotests hold particular significance for specific populations, such as drivers and pilots, and are instrumental in assessing distance stereoacuity to evaluate treatment outcomes and guide the development of treatment plans for conditions like intermittent exotropia. Previous research indicates that individuals with intermittent exotropia exhibit reduced distance stereovision compared to those without this condition, while individuals with persistent strabismus demonstrate an absence of distance stereoacuity.[1] The Distance Randot Stereotest, designed for viewing with polarized glasses at a 3m distance[2] has been proved to be simple, efficient, and effective for reliable and valid measurements of distance stereoacuity.[3]

Advancements in 3D display technology has spurred the development of computer-based stereotests. In 2011, Jongshin Kim developed a 46-inch polarized stereoscopic monitor to assess contour-based distance stereovision at a distance of 3 m.[4] Angelo Gargantin measured random dot stereoacuity using a three-dimensional (3D) monitor with NVIDIA active LCD shutter glasses at distances ranging from 0.4 to 2 m.[5] Angelo Gargantin, Sang Beom Han and subsequently, Huang Wu developed 3D displays with NVIDIA active LCD shutter glasses for stereoacuity evaluation at testing distances between 0.5 and 4.1 m.[6,7]

Computer-based stereotests with variable stereograms and adjustable disparity levels effectively minimize learning effect, also known as memory pattern retention, which commonly affects card-based stereograms in repeated tests.[8,9] Additionally, 3D self-luminous monitor displays provide consistent high brightness that is less impacted by ambient lighting compared to card-based tests[10,11] However, brightness reduction can occur with polarized 3D glasses.[12] To address this, Han SB developed a new method using NVIDIA active liquid-crystal shutter glasses, which minimizes interference with stereogram brightness.[6] However, its display effect may be influenced by ambient light.[13,14] Glasses-free random-dot stereotests, such as those using multi-view display systems by McCaslin[15] and Jonghyun Kim,[16] eliminate the negative effects of 3D glasses but offer optimal stereoscopic perception only at specific viewing angles.

Currently, long-distance stereopsis testing methods have evolved from printed versions to electronic formats. However, auxiliary glasses, such as polarized glasses, may interfere with test results. Additionally, the grating-based naked-eye testing method limits the examiner's gaze angle, making it essential to avoid inaccuracies caused by improper gaze alignment. In response to these limitations, a novel glasses-free distance random-dot stereotest system (GFDRDSS) was developed, using an eye tracking method to alternately project paired random-dot stereograms to each eye, enabling glasses-free stereotesting at a 5-m distance. In preliminary clinical trials,[17] stereoacuity in 12 volunteers was assessed using Randot tests, Yan's charts, Distance Randot stereotests, and GFDRDSS. GFDRDSS showed good concordance with the other three stereotests. To further validate GFDRDSS, an analysis of normative, testability, validity, and monocular cue recognition was conducted among young adults with normal vision. The findings are presented in this report.

Materials and Methods

This clinical examination was conducted at the Sixth Medical Center of the People's Liberation Army (PLA) General Hospital in China.

Participants

The study included 185 male volunteers aged 17–20 years (mean age: 18.53±0.66 years) from the 12th grade of high school. Visual acuity was assessed using a standard logarithmic visual acuity chart at 5 m and a Jaeger chart at 0.40 m, with results recorded as logα (where α denotes visual angle in arcminutes). The study protocol adhered to the principles outlined in the Declaration of Helsinki.

Inclusion Criteria

1. Uncorrected visual acuity of 0.1 logMAR or better, as measured by the standard logarithmic visual acuity chart, and 0 or better by the Jaeger chart in each eye.

2. An interocular difference in optometric diopter of no more than 2 diopters.
3. No manifest tropia at distance or near fixation, as assessed by the Hirschberg test, alternate cover test, cover-uncover test, and simultaneous prism and cover test.

Exclusion Criteria

1. Presence of any ocular or systemic disease.
2. History of ocular or neurological disorders.

In order to complete the different tests, the participants were assigned to one of three groups based on their recruitment order.

GFDRDSS System

The GFDRDSS utilizes a glass-free 3D system equipped with an eye tracking backlight control system and a specialized random-dot stereotest (RDS) software.[14] A single-user eye tracker monitors the viewer's eye position and movement in real time. Based to these positional data, the system's directional backlight control mechanism on the LCD panel (display size: 23-inch screen; resolution: 3840 × 2160; frame rate: 120 hz) creates two exit pupils that sequentially project left and right images to the corresponding eyes.

An interface management program operates on an additional 14-inch laptop. The corresponding RDS software provides 15 different RDS graphs (created with Adobe Photoshop CS5 and based on Yan's Stereoscopic Test Charts) for each of six disparity levels (800, 400, 200, 100, 60, and 40 arcsec) at a viewing distance of 5 m. For each level, up to 3 unique graphs, including a capital letter, an Arabic numeral, and a simple geometric shape, are available, with each graph randomly selected from five possible options and displayed for a maximum of 20 seconds. Upon correct identification of any of the three stereograms, the next disparity level is presented.

Protocol

Each participant was assigned a unique identification number in the order of participation. Participants with odd numbers completed the GFDRDSS test first, while those with even numbers began with the Distance Randot test. An interval of at least 5 minutes separated the two tests. Test-retest evaluations were scheduled one day apart.

GFDRDSS Test

Each participant was seated 5 m in front of the autostereoscopic display. The presenter ensured that both eyes were detected and tracked by the system. General information (name, gender, age, and visual acuity) of the participant was recorded. The quantitative test started at 800 arcsec-level. If the participant correctly identified any shapes at this level, the test would proceed to the next higher level (proceeding to 400 arcsec-level, and so on), until the participant could no longer correctly identify all three RDS shapes presented at a particular level. The smallest disparity that the participant discerned correctly was recorded as his stereoacuity.

Distance Randot Stereotest (Version 2; Stereo Optical Co. Inc., Chicago, Illinois, USA)

Participants viewed the test cards through polarized lenses at a distance of 3 m. Testing started at the 400 arcsec level, progressing to 200, 100, and 60 arcsec levels if the participant could correctly identify either shape at each level. The stereoacuity was recorded. The viewing time for each stereogram was limited to 20 seconds.

Induced Monocular Blur Test

Bangerter filters with 0.1 filter density (Fresnel Prism and Lens Co., LLC, Eden Prairie, MN) were applied to the inner surface of Plano trial lenses over the participant's right eye during both distance stereotests.

Revised GFDRDSS

In the GFDRDSS, a random dot image is projected to the participant's left eye, while a corresponding image containing horizontal disparity information is projected to the right eye. In this configuration, dots within the graphic area shift a certain distance according to the designed disparity size, while background dots remain stationary. In the

revised version of the GFDRDSS, the background dots also shift 5 mm to the right in the right-eye image, further enhancing the elimination of monocular cues.

Monocular Cue Test

After the left eye was covered, participants were instructed to identify the shapes using only the right eye. The smallest disparity level that was correctly identified was recorded for each individual. Each participant underwent the Distance Randot® stereotest, GFDRDSS, and revised GFDRDSS in separate trials.

Test Environment

All stereotests were performed indoors with ambient illumination levels recorded between 250 and 400 lux, measured at eye level using a digital light meter (TES-1330A, TES Electrical Electronic Corp. Taipei, Taiwan).

Statistical Analysis

Data were processed using SPSS 22.0 (IBM SPSS Inc)., with all stereoacuity measurements transformed to log (arcsec) values. For statistical analysis, stereoacuity values at the maximum disparity level (where stereograms of 800 arcsec in GFDRDSS or 400 arcsec in Distance Randot could not be identified) were assigned a value of 1000 arcsec.

The Wilcoxon matched-pairs signed rank test was used to compare the differences between paired groups. For normative and validity data analysis, stereoacuity results were categorized into four levels: Level 1 (40–60 arcsec), Level 2 (100 arcsec), Level 3 (200 arcsec), and Level 4 (≥400 arcsec). For reliability data analysis, stereoacuity differences between two measurements were grouped into seven levels for GFDRDSS (0, 20, 40, 60, 100, 140, 900 arcsec) and five levels for Distance Randot (0, 40, 100, 300, 900 arcsec). For monocular cue data, the Wilcoxon signed rank test was used to compare results between each pair of groups.

Results

Normative Data for the Distance Stereotest

The flowchart of this study is shown in Figure 1. In the GFDRDSS test, 31 of the 38 participants (81.58%) achieved a stereoacuity of 60 arcsec or better, with the remaining seven achieving 100 arcsec. In the Distance Randot test, 18 participants (47.37%) achieved 60 arcsec, 97.37% achieved ≤100 arcsec, and only one participant (2.63%) achieved 200 arcsec (Table 1). Statistical analysis using the Wilcoxon signed ranks test revealed a significant difference in stereoacuity results between the two stereotests, suggesting that GFDRDSS has higher sensitivity compared to Distance Randot.

Validity With Monocular Blur

The visual acuity in right eyes of 38 participants from normative data Group 1 decreased from −0.02±0.09 (range −0.18 to 0.10) to 0.55±0.09 (range 0.4 to 0.7), resulting in experimental monocular blur using a Bangerter filter. For those tested by GFDRDSS, 60.53% (23/38) degraded to Level 4 (≥400 arcsec), and 89.47% (34/38) got Level 3. In the Distance Randot test, 76.32% (29/38) degraded to Level 4, 89.47% (34/38) to 200 arcsec as Level 3, and 10.53% (4/38) had stereoacuity as 100 arcsec (Table 2). Only one participant demonstrated consistent results within one disparity level across both tests, suggesting that the patient's perception of the stereogram is more likely due to monocular cues rather than binocular disparity analysis.

Reliability of the Distance Stereotest

Test-retest reliability data from 58 participants in Group 2 are presented in Tables 3 and 4. For the GFDRDSS, identical test-retest results were observed in 70.69% (41/58) of participants, with 94.83% (55/58) achieving results within one disparity level. Two participants showed greater differences: one with a disparity difference of 60 arcsec (100 to 40) and another with a difference of 140 arcsec (200 to 60). For the Distance Randot test, identical results were noted in 79.31% (46/58) of participants, with 96.55% (56/58) achieving results within one disparity level, while one participant (1.72% (1/58)) had a 300 arcsec-difference (400 to 100 arsec). Additionally, one participant who initially had no measurable distance stereoacuity demonstrated improvement to 100 arcsec upon retesting in both stereotests.

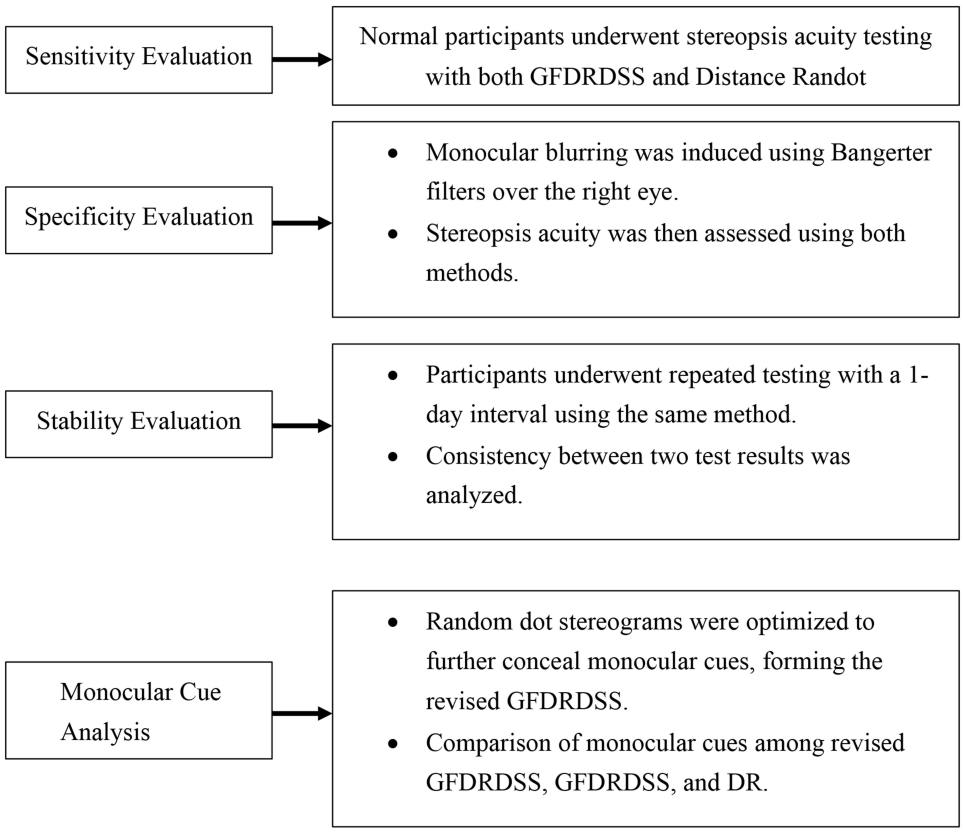

Figure 1 Study flowchart.

Monocular Cue

Using the GFDRDSS test, 38.20% (34/89) of participants were able to identify stereograms with one eye (12.36% identified ≤ 400 arcsec level images, 25.84% only identified 800 arcsec images). In contrast, with the Distance Randot test, 16.85% (15/89) of participants were able to correctly identify images with ≤ 400 arcsec disparity using one eye. In addition, 3.4% (3/89) reached the same level with GFDRDSS, while 4.5% of participants (4/89) achieved a monocular cue level of 200 arcsec with the Distance Randot. Additionally, 2.2% (2/89) achieved 100 arcsec with GFDRDSS, and 1.1% (1/89) reached 100 arcsec in the Distance Randot test. Notably, only one participant (1.1%) could identify images at the 800 arcsec level, with the remaining 88 participants unable to recognize stereograms with the revised GFDRDSS

Table 1 Stereoacuity Data Comparing Youth with Normal Visual Acuity and Ocular Alignment (n = 38) Using the GFDRDSS (5-meter Distance) vs Distance Randot (3-meter Distance)

GFDRDSS (stereoacuity level)	Distance Randot (stereoacuity level)				Z	p
	1	2	3	4		
1	17	14	0	0	−3.44	0.00058<0.05
2	1	5	1	0		
3	0	0	0	0		
4	0	0	0	0		

Note: Identical results between 2 tests are highlighted in gray.

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Table 2 Stereoacuity Data from Participants with Induced Monocular Blur (n = 38) Assessed by GFDRDSS (5-meter Distance) and Distance Randot (3-meter Distance)

GFDRDSS (stereoacuity level)	Distance Randot (stereoacuity level)				Z	p
	1	2	3	4		
1	0	1	0	0	−1.48	0.1146>0.05
2	0	0	2	1		
3	0	2	3	6		
4	0	1	0	22		

Note: Identical results between 2 tests are highlighted in gray.

Table 3 Test-Retest Repeatability Data for Group 2 (n = 58) Using GFDRDSS (5-meter Distance)

Test	Retest							Z	p
	40	60	100	200	400	800	1000		
40	22	4	0	0	0	0	0	−2.0612	0.0393 <0.05
60	6	9	1	0	0	0	0		
100	1	3	9	0	0	0	0		
200	0	1	1	1	0	0	0		
400	0	0	0	0	0	0	0		
800	0	0	0	0	0	0	0		
1000	0	0	1	0	0	0	0		

Note: Identical results between two tests are highlighted in gray. Minor differences within one disparity level are highlighted in light gray.

Table 4 Test-Retest Repeatability Data for Group 2 (n = 58) Using Distance Randot (3-meter Distance)

Test	Retest					Z	p
	60	100	200	400	1000		
60	37	1	0	0	0	−2.8343	0.0046<0.05
100	5	8	0	0	0		
200	0	4	1	0	0		
400	0	1	0	0	0		
1000		1	0	0	0		

Note: Identical results between two tests are highlighted in gray. Minor differences within one disparity level are highlighted in light gray.

(Table 5 - 7). Statistically significant differences were observed between monocular cue data from the revised GFDRDSS and those from both Distance Randot and GFDRDSS tests; however, the differences between GFDRDSS and Distance Randot were not significant (see Figure 2).

Table 5 Monocular Data (n = 89) Comparing Revised GFDRDSS (5-meter Distance) and Distance Randot (3-meter Distance)

Revised GFDRDSS (stereoacuity level)	Distance Randot (stereoacuity level)				Z	p
	1	2	3	4		
1	0	0	0	0	−2.12	0.033895<0.05
2	0	0	0	0		
3	0	0	0	0		
4	0	1	4	84		

Note: Identical results between 2 tests are highlighted in gray.

Table 6 Monocular Data (n = 89) Comparing Revised GFDRDSS with GFDRDSS

Revised GFDRDSS (stereoacuity level)	GFDRDSS (stereoacuity level)				Z	p
	1	2	3	4		
1	0	0	0	0	−2.07	0.038434<0.05
2	0	0	0	0		
3	0	0	0	0		
4	0	2	3	84		

Note: Identical results between two tests are highlighted in gray.

Table 7 Monocular Data (n = 89) Comparing GFDRDSS (5-meter Distance) and Distance Randot (3-meter Distance)

GFDRDSS (Stereoacuity level)	Distance Randot (Stereoacuity level)				Z	p
	1	2	3	4		
1	0	0	0	0	−1.00	0.317311>0.05
2	0	1	1	0		
3	0	0	3	0		
4	0	0	0	84		

Note: Identical results between two tests are highlighted in gray.

Discussion

Most computer-based stereotests rely on polarized glasses to separate binocular image displays. Conventional glasses-free 3D displays, which generate stereoscopic vision, are limited to fixed viewing points. The novel GFDRDSS system, however, incorporates an eye tracking system and an active backlight, enabling real-time tracking of each eye's position. This allows the active backlight to project images directly to both eyes without the need for glasses, expanding the range of viewing angles for distance stereotesting.[18] The viewing distance of GFDRDSS was set at 5 m to align with the standard visual acuity test distance. A new glasses-free stereotest system, the GFDRDSS, was developed to evaluate distance stereovision with glass-free 3D display.[19] Further quantitative data were collected from young adults with normal vision and eye position to analyze the sensitivity, validity, and reliability of the GFDRDSS. An ideal stereotest should have the following characteristics: high

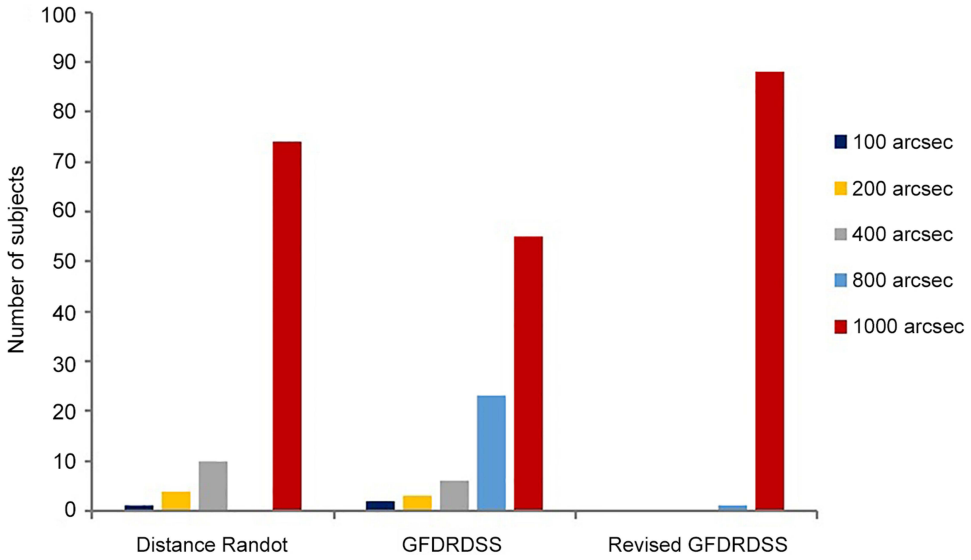

Figure 2 Monocular stereoacuity data as measured by three detection methods.

sensitivity, effectiveness, and stability, with no significant monocular cues. In this study, we selected the clinically widely used Distance Randot as the control method to evaluate our approach based on these aspects.

Various factors are known to affect stereovision, including strabismus,[19] amblyopia,[20] anisometropia, aniseikonia[21] and aging.[22] To mitigate these influences, the study included high school seniors aspiring to become pilots. This cohort, characterized by normal vision and eye position, perfect cognitive abilities, and satisfactory reading distance stereovision, presented no significant refractive errors or anisometropia. Therefore, these young individuals can be considered as the population with normal stereoscopic vision. Gender differences were not considered in this study due to the lack of evidence suggesting any impact of gender on stereovision performance.

The normative data acquired through GFDRDSS showed a tight clustering around 60 and even 40 arcsec, in contrast to the wider distribution observed with the Distance Randot, which included some results as low as 200 arcseconds. The high-retest reliability and tight clustering of normative values in the 17–20-year age group indicate that GFDRDSS may be particularly suitable for testing stereovision within this population, suggesting that GFDRDSS has higher sensitivity than Distance Randot. In a previous study by Valeria L. N. Fu, the Distance Randot test was identified as a sensitive method for evaluating binocular status.[23] However, the data collected using the GFDRDSS in the present study demonstrated a statistically significant improvement over the results obtained from the Distance Randot Stereotest.

Valeria's study of adults aged 20 to 36 years found that all participants achieved a stereoacuity of 60 arcseconds using the Distance Randot test.[24] The relatively low ratio of participants reaching this level in our study could be attributed to factors such as inadequate lighting leading to non-uniform brightness. Several participants reported that the images appeared dark or reflective, which may have impacted visibility. Additionally, the limited viewing time of 20 seconds may have impacted accuracy of the responses. While self-luminous 3D plays are rarely influenced by ambient illumination compared to card-based tests.[10] Computer-based stereotests offer advantages over card-based methods, by avoiding problems such as reflective light interference, degradation in image clarity with card aging, and restrictions in setting stereogram parameters (eg contrast, color, size, texture, and dot density). The GFDRDSS demonstrates significant utility in assessing distance stereoacuity in populations with normal visual function. Even in real-world application scenarios with insufficient and uneven lighting, it demonstrates satisfactory sensitivity.

In the second phase of this study, experimental monocular blur was induced in the left eyes of participants in Group 1 using Bangerter filters with a density of 0.1. A previous study has shown that experimental monocular vision loss can lead to a decline in stereoscopic visual function.[25] We used this experiment to evaluate and compare the effectiveness of the two methods. The specificity of the GFDRDSS was then compared to the Distance Randot stereotest, which served as a control. The results showed a decline in stereoacuity corresponding to a reduction in monocular visual acuity, with both

tests indicating a stereoacuity decline to ≥200 arcsec in 89.47% of participants.[26] Notably, one participant exhibited only a single level of stereoacuity decline (from 40 arcsec to 60 arcsec with GFDRDS and from 60 arcsec to 100 arcsec with the Distance Randot test) in response to monocular blur (visual acuity change from 0 to 0.4), which was consistent with the outcome following complete occlusion of his left eye. This suggests that certain individuals may rely on monocular cues, although this was observed in a significantly lower incidence for random dot sterotests compared to contour-based stereotests.[27] We further discussed this aspect in the following monocular cues analysis section.

Test-retest reliability was assessed in Group 2 at intervals of one day. The GFDRDS showed identical results upon retesting in 70.69% of participants (41/58), while the Distance Randot test yielded identical results in 79.31% (46/58) of participants. The GFDRDS included eight disparity levels, ranging from 800 to 40 arcsec, with the minimum disparity difference set at 20 arcsec, while the Distance Randot test utilized four levels (400 to 60 arcsec) with disparity intervals exceeding 40 arcsec. Considering the differences in disparity level settings between the two tests, no main effect was observed in test-retest reliability. Additionally, one participant in this group was unable to recognize any stereograms in the GFDRDS or Distance Randot during the initial test, despite achieving a Titmus result of 40 arcsec at reading distance. However, on the subsequent day, this participant's stereoacuity improved to 100 arcsec in both tests. Unlike contour-based stereotests, random dot stereograms require not only stereovision but also a higher level of perceptual learning, necessitating extended recognition time.[28] In this study, the recognition time for each stereogram was limited to 20 seconds, which may explain the initial lack of stereoacuity, suggesting that extended viewing times may be beneficial for clinical random-dot stereotests.

Random-dot stereotests are widely regarded as effective for eliminating monocular cues.[26] The stereoscopic visual test evaluates binocular disparity stimuli to produce stereoscopic vision. The presence of monocular cues may cause individuals with binocular vision abnormalities to mistakenly recognize a stereogram as possessing stereoscopic vision. Therefore, an ideal stereoscopic visual test should minimize the presence of monocular cues. Although the random dot plot hides parallax information, a relatively regular contour may still form between the moving parallax image and background random points. This contour could potentially be detected by individuals with heightened sensitivity to monocular cues. In the effectiveness analysis section, we found that GFDRDSS still did not completely eliminate monocular cues. Therefore, we improved the random dot design by further shifting the background points to blur the contour of the stereogram. This led to the creation of a revised version of the GFDRDSS. Monocular viewing assessments indicated that the revised GFDRDSS effectively minimized monocular cues compared to both the original GFDRDSS and the Distance Randot test. This indicates that the monocular cues present in the GFDRSS are not due to hardware defects, but rather stem from the method used in the creation of the stereogram. The displacement of contour-based edges on a random-dot background could be perceived through monocular depth such as lateral displacement, linear perspective, and image size.[16] The background random dots were shifted in the opposite direction of the stereo shapes, while the dots within the stereo shapes remained stationary. This technique effectively blurred the contours of the stereo shapes, thereby reducing the influence of monocular cues. This approach is consistent with previous studies emphasizing the removal of monocular cues from the display.[29] Notably, some participants experienced mild vertigo when viewing revised GFDRDSS and found it more challenging to distinguish stereo shapes when using the revised stereograms compared to the original GFDRDSS. We hypothesize that older individuals or those with symptoms of dizziness may experience significant discomfort or vertigo when viewing the revised GFDRDSS. If used in clinical settings, this may pose a safety risk. These findings suggest that further refinements are needed to improve this method of monocular cue suppression. Further examination of monocular cues and their impact on stereoacuity will be explored in subsequent sections of this research to better understand their role in stereovision and the performance of the GFDRDSS.

The novel glasses-free distance stereotest (GFDRDSS) demonstrated higher sensitivity, consistent efficacy, and reliability compared to the Distance Randot test in this study, suggesting promising prospects for clinical application. However, this research has some limitations. All participants were recruited from a population of high school students with normal visual acuity, thus limiting the clinical data analysis to patients with strabismus and amblyopia. This study used data from young individuals with normal vision and eye alignment. In clinical practice, GFDRDSS can be applied to people of all ages, as well as those with different visual statuses and eye alignments. These factors need to be further analyzed and summarized after application to other populations. Additionally, the sample size was relatively limited.

Considering that the GFDRDSS projects binocular images alternately to the viewer's corresponding eyes, potentially involving a distinct mechanism from classical stereotests using polarized glasses to separate binocular images, further clinical examination in individuals with strabismus is warranted and will be the focus of future studies. Although GFDRDSS offers a practical tool for assessing distance stereovision, it entails relatively high maintenance costs and has portability limitations compared to the Distance Randot test, underscoring the need for continued research.

Conclusion

A new glasses-free random dot stereotest, GFDRDSS, was developed using eye detection and location methods to evaluate stereoacuity at a 5-m distance. Clinical testing with participants with normal vision revealed that GFDRDSS performs comparably or superiorly to the Distance Randot Stereotest. These results support further research, including applications in individuals with strabismus.

Abbreviations

Glasses-free distance random-dot stereotest system, (GFDRDSS); three-dimensional, (3D); random-dot stereotest, (RDS).

Data Sharing Statement

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki (as was revised in 2013). The study was approved by Ethics Committee of the Third Medical Center of Chinese PLA General Hospital. All participants provided written informed consent for their involvement in the study. In cases where participants were under the age of 18, informed consent was additionally obtained from their parents or legal guardians.

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Disclosure

The authors declare that they have no competing interests.

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