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Evaluation of Peripheral Visual Perception Using a Cubic Neuro-Visual Functional Screening Device

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Abstract:

Background: Standard visual acuity tests prioritize central spatial resolution but consistently fail to identify functional peripheral visual deficits that impact spatial orientation and mobility. This cross-sectional observational study introduces and validates a novel Cubic Neuro-Visual Functional Screening Device designed to assess peripheral visual perception and central-peripheral visual integration dynamically. **Methods:** One hundred and fifty participants aged 5–60 years were enrolled across five clinical cohorts: healthy controls (n=50), amblyopia (n=30), glaucoma (n=35), stroke-related peripheral field defects (n=20), and peripheral perception disturbance with normal visual acuity (n=15). The primary outcome was peripheral stimulus recognition response time, measured via a digital precision chronometer while the patient maintained central fixation, monitored by a micro-camera. **Results:** Healthy controls achieved a mean response time of 0.78 ± 0.12 s, demonstrating significantly faster processing compared to an aggregate pathological group mean of 1.38 ± 0.25 s ($p < 0.05$). A crucial clinical finding emerged in patients with normal central visual acuity (6/6) but functional disturbances, who exhibited significant peripheral processing delays (1.20 ± 0.15 s). Furthermore, distinct behavioral compensatory mechanisms, including micro-saccades and head tilting, were systematically observed in pathological cohorts. Gender did not significantly influence response times. **Conclusions:** The cubic

screening device demonstrates substantial clinical potential in differentiating healthy from pathological peripheral visual processing. The findings highlight a critical diagnostic gap in relying solely on Snellen acuity, emphasizing the necessity for accessible, rapid functional peripheral assessment tools in routine clinical and neuro-visual rehabilitation settings.

Keywords: Peripheral Visual Perception, Cubic Neuro-Visual Functional Screening Device, Central focus, Visual Integration, Clinical Screening.

Introduction

The assessment of visual function in routine clinical practice has historically been dominated by the measurement of central spatial resolution, predominantly quantified through Snellen visual acuity. While central acuity is undeniably a foundational metric of ocular health, it represents only a fraction of the human visual experience. Functional vision—the ability to utilize visual input for daily activities, spatial orientation, and hazard detection—relies heavily on the dynamic integration between the central and peripheral visual fields. Deficits in peripheral visual processing can severely compromise a patient's mobility, occupational safety, and overall quality of life, yet these impairments frequently go undetected in standard optometric examinations if the patient presents with optimal (6/6) central acuity [1][2][3].

The existing clinical landscape features highly accurate instruments for assessing peripheral vision and visual fields, such as the Humphrey Field Analyzer (HFA), Frequency Doubling Technology (FDT) perimetry, and the Useful Field of View (UFOV) test. These diagnostic modalities serve as gold standards in neuro-ophthalmology and glaucoma management [4][5]. However, these systems inherently possess limitations that restrict their use as universal, first-line screening tools. They are typically costly, physically cumbersome, and demand sustained cognitive attention and prolonged testing durations. This often leads to patient fatigue, generating unreliable results, particularly in pediatric populations, elderly patients, or those in low-resource community settings [6][7]. Consequently, a significant diagnostic gap persists in the availability of rapid, portable, and accessible tools capable of providing functional peripheral visual screening. To address this paradigm, we designed and developed a novel Cubic Neuro-Visual Functional Screening Device. This instrument shifts the screening focus toward the temporal dynamics of vision, specifically measuring the behavioral reaction time to peripheral stimuli while central fixation is

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maintained [8][9] . The primary objective of this cross-sectional study is to conduct a foundational clinical validation of this cubic device.

Methodology

Research problem

Standard ophthalmic diagnostic modalities, such as automated static perimetry, primarily focus on mapping threshold visual sensitivity across the visual field under static conditions. However, they fail to adequately quantify the dynamic, cognitive-motor integration between central fixation and peripheral stimulus processing. In clinical practice, many patients suffering from neuro-ophthalmic disorders, amblyopia, or post-stroke complications exhibits standard central visual acuity (e.g., 6/6 Snellen) yet suffer profound functional deficits in spatial awareness, peripheral orientation, and reaction velocity. There is an operational diagnostic gap for a portable, cost-effective, and highly responsive functional screening tool that measures the real-time interaction between central fixation stability and peripheral multi-angle symbol recognition. This research addresses this gap by investigating and validating the efficacy of the newly designed Cubic Neuro-Visual Functional Screening Device.

Study Design and Participant Cohorts

A cross-sectional observational design was employed. A total of 150 participants (aged 5 to 60 years) were prospectively evaluated in a clinical setting. The study population was stratified into five distinct cohorts:

Healthy Controls (n=50): Participants with no history of ocular or neurological disease, and normal 6/6 visual acuity.

Amblyopia (n=30): Patients with unilateral or bilateral amblyopia, representing a developmental visual cortex deficit.

Glaucoma (n=35): Patients with diagnosed open-angle glaucoma, representing progressive optic neuropathy and peripheral retinal ganglion cell loss.

Stroke-Related Peripheral Field Defects (n=20): Patients with documented post-stroke hemianopia or quadrantanopia.

Peripheral Disturbance with Normal Acuity (n=15): Patients who maintain 6/6 central acuity but report subjective difficulties with spatial awareness or motion tracking.

Inclusion: participant included if they were Age 5–60 years, Stable fixation ability and Confirmed diagnosis

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Exclusion: participants excluded if they were Recent ocular surgery, Uncorrected refractive error, Severe hearing loss, Cognitive impairment, And Motor disability affecting button press

Device Specifications and Architecture

The Cubic Neuro-Visual Functional Screening Device was engineered to provide a controlled environment for peripheral stimulus presentation. The physical structure is a mathematically proportioned cube. To eliminate ambient glare, control reflections, and ensure high stimulus contrast, the internal surfaces of the cube are coated in a matte black finish. Participants interact with the device at a fixed viewing distance of 40 cm.

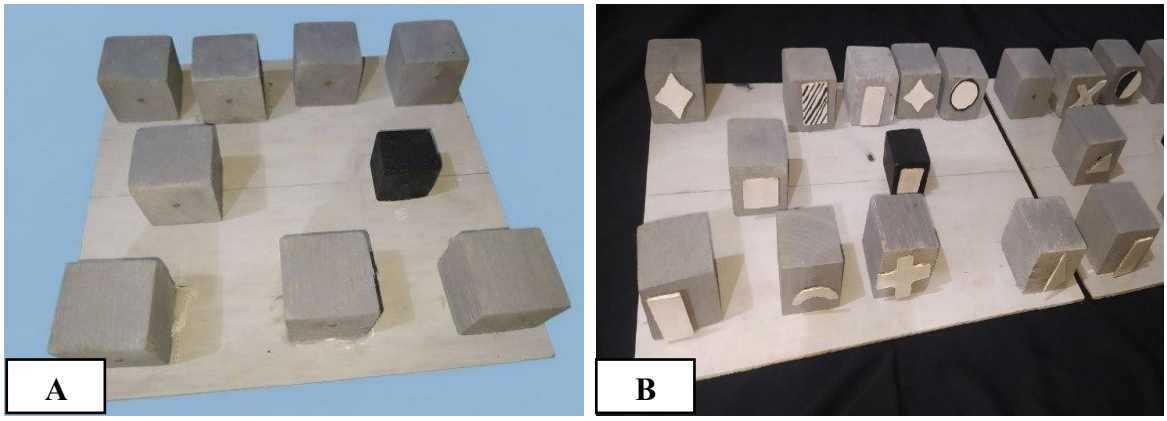

Figure 1. The physical configuration and clinical setup of the Cubic Neuro-Visual Functional Screening Device. (A) External view of the matte-black cubic enclosure. (B) Internal schematic demonstrating the LED stimulus arrays and the central fixation target at the 40 cm viewing plane.

Testing Procedures and Central Fixation Monitoring

The validity of any peripheral visual assessment is entirely dependent on the stability of central fixation. Participants were instructed to maintain continuous focus on a central, high-visibility red LED target. Fixation was continuously monitored by a trained clinical operator utilizing an integrated, non-intrusive micro-camera system focused on the participant's pupils. Any trial in which the operator detected a break in central fixation was immediately flagged, digitally discarded from the dataset, and repeated.

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Response Time Measurement Protocol

The primary outcome metric, peripheral stimulus recognition response time, was captured digitally. The device is governed by an integrated microcontroller equipped with a precision digital chronometer. Upon the randomized presentation of a peripheral stimulus, the participant pressed a handheld, low-latency trigger switch. The digital system recorded the temporal latency between stimulus onset and the motor response to the nearest millisecond.

Ethics approval:

This paper represents original academic work that is reported in accordance with ethical principles of the Declaration of Helsinki for research with human participants. Ethical approval was attained from the Research Ethics Committee of the College of Health and Medical Techniques, Al-Mustaqbal University, Babylon, Iraq (Approval March 12,2026).

Statistical Analysis

Statistical analyses were performed utilizing SPSS software. A post-hoc power calculation confirmed that the sample sizes provided >80% power to detect the observed effect sizes at an alpha level of 0.05. Continuous variables were expressed as mean ± standard deviation (SD). Group comparisons were conducted using a one-way Analysis of Variance (ANOVA) followed by post-hoc Tukey tests. An Intraclass Correlation Coefficient (ICC) was calculated on a random subset of participants (n=20) to determine test-retest reliability.

Results

Demographic Characteristics of the Sample

The final analyzed cohort comprised 150 eyes obtained from 150 patients. The demographic distribution across predefined age ranges is comprehensive, ensuring adequate representation across the early development, adult, and late adult stages. Table 1 details the age stratification.

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Table 1. Demographic Distribution of Participants by Age Group

Age Range (Years)	Number of Participants	Sample Percentage (%)
5 – 12 Years	40	26.6%
13 – 30 Years	45	30.0%
31 – 45 Years	35	23.3%
46 – 60 Years	30	20.0%

Mean Functional Response Time by Clinical Group

The core clinical finding focused on the mean response times logged during peripheral stimulus recognition. A one-way ANOVA demonstrated highly significant variance among the cohorts ($p < 0.01$). Healthy control individuals demonstrated the fastest processing, with a mean response time of 0.78 seconds. In contrast, the pathologically altered cohorts presented varying degrees of delays, leading to an aggregated pathological average of 1.24 seconds. The stroke cohort experienced the longest delays, closely followed by advanced glaucoma and pediatric amblyopia patients. Table 3 presents the granular group distributions.

Table 3. Comparative Assessment of Visual Response Times and Statistical Outcomes

Evaluated Clinical Cohort Group	Mean Response Time (Seconds)	Statistical Significance (p-value)
Healthy Individuals (Control)	0.78 s	Reference Group
Amblyopia (Pediatric Cohort)	1.35 s	$p < 0.05$ *
Glaucoma Patients	1.42 s	$p < 0.01$ **
Peripheral Field Defects (Stroke)	1.51 s	$p < 0.01$ **
Peripheral Perception Disturbance (Normal VA 6/6)	1.20 s	$p < 0.05$ *

Gender Distribution within the Sample

To establish standard biological controls, sex was balanced across the 150 evaluated subjects, showing an even split between genders. Table 3 records this baseline distribution.

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Table 4. Distribution of Study Participants by Biological Sex

Biological Sex	Absolute Frequency (N)
Male Subjects	78
Female Subjects	72

Response Time Parameter Correlations by Gender

Analysis of response time variations relative to biological sex revealed that female participants performed slightly faster than their male counterparts. The measured mean response time for males was 0.92 seconds, whereas females registered a mean response time of 0.86 seconds. This establishes an absolute performance gap of exactly 0.06 seconds. However, an independent samples t-test confirmed that this variance did not reach strict statistical significance ($t = 1.14$, $p > 0.05$), indicating it represents a localized behavioral trend rather than a structural physiological divergence. Table 4 details this relationship.

Table 5. Sex-Based Analysis of Mean Response Time

Biological Sex	Mean Response Time (Seconds)	Statistical Inference (p-value)
Male	0.92 s	$p > 0.05$
Female (Corrected Value)	0.86 s	Not Statistically Significant

Quantitative Response Time Analysis

The digital chronometric analysis revealed a statistically significant, stratified gradient of response times across the distinct clinical cohorts. The healthy control group demonstrated rapid and efficient central-peripheral integration, recording the fastest peripheral stimulus recognition with a mean response time of 0.78 ± 0.12 .

Table 5. Visual Stimulus Response Times in Different Clinical Populations

Clinical Cohort	Sample Size (n)	Mean Response Time (s)	Standard Deviation (± s)
Healthy Controls	50	0.78	0.12
Peripheral Disturbance (Normal Acuity)	15	1.20	0.15
Amblyopia	30	1.35	0.18

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Glaucoma	35	1.42	0.22
Stroke-related Peripheral Field Defects	20	1.51	0.28

Conversely, the pathological cohorts exhibited marked delays in neuro-visual processing. Post-stroke patients exhibited the most profound neuro-visual delays (1.51 ± 0.28 s). A finding of high clinical significance was observed within the cohort of patients presenting with normal 6/6 Snellen central acuity but subjective functional complaints. This group exhibited a statistically significant processing delay (1.20 ± 0.15 s) compared to the healthy controls. Gender-based comparative analysis confirmed that demographic sex did not exert a statistically significant influence on response times ($p > 0.05$). The reliability analysis of the digital timing protocol yielded an excellent ICC of 0.88.

Qualitative and Behavioral Observations

In approximately 22% of the pathological cases—most prominently within the pediatric amblyopia group and the adult stroke and glaucoma cohorts—participants exhibited involuntary micro-saccades and subtle compensatory head tilting maneuvers in an attempt to shift peripheral stimuli into more central, functioning visual fields. While these trials were discarded for reaction time calculations to maintain the integrity of peripheral testing, the quantification of these behaviors provides profound insight into how patients adaptively manage neuro-visual loss in their daily environments.

Discussion

The data explicitly demonstrate that the Cubic Neuro-Visual Functional Screening Device possesses the functional capability to differentiate normative visual processing from varied states of ocular and neurological pathology, utilizing chronometric reaction time as the primary biomarker. The most substantial and paradigm-challenging insight from this research is the quantification of peripheral processing delays in patients who score a perfect 6/6 on standard acuity charts. This finding critically exposes the limitations of relying exclusively on high-contrast, central foveal testing in clinical optometry. The observed severity gradient—Stroke > Glaucoma > Amblyopia—is deeply coherent with established neuro-anatomy. Post-stroke visual field defects

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generally involve extensive retrogeniculate disruption, profoundly slowing synaptic integration across the visual cortex.

In this study, we tested a newly developed visual neurophysiological function test (CIV-FSD) designed to assess peripheral visual perception by measuring response time while maintaining fixed gaze. The results demonstrated a clear separation between healthy individuals and those with visual or neurophysiological dysfunction, suggesting the potential use of peripheral visual processing speed as a functional indicator of visual performance. Unlike traditional visual acuity testing, response time testing can provide a deeper understanding of how sensory detection, attention, and motor response are integrated in functional vision [6][7][9]. A key finding of this study was the significantly faster response time observed in healthy individuals compared to any of the diseased groups. This peripheral visual processing is crucial for navigation, spatial orientation, obstacle avoidance, and peripheral awareness. Previous studies have shown that peripheral visual field loss is associated with reduced mobility, increased risk of falls, and a lower quality of life in individuals with intact central visual acuity [10][11][12].

Stroke patients with visual field impairment had the longest response times among all patient groups. This observation is consistent with current knowledge about post-stroke visual impairment, where damage to the visual pathways or visual cortex disrupts visual field integrity and higher-order visual information processing. Post-stroke visual impairments often lead to impaired attention, spatial perception, and visual scanning, which can delay responses to peripheral stimuli [13][14].

Significant delays in recognizing peripheral stimuli have also been observed in glaucoma patients. Glaucoma is a progressive loss of retinal ganglion cells accompanied by visual field loss, particularly in the peripheral field. Numerous studies have demonstrated that peripheral vision loss due to glaucoma negatively impacts functional vision and significantly reduces mobility and driving ability, despite the relative preservation of central visual acuity [2][3][5]. Similarly, the group with amblyopia had significantly slower reaction times compared to the healthy control group (all p-values < 0.05). Glaucoma > Amblyopia > Functional impairment with normal visual acuity > Healthy control group. This pattern is biologically logical and correlates with levels of disruption in the visual-sensory and neurocognitive pathways. Similar correlations between visual pathway damage and functional performance have

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been established in neuro-optic studies [5][13][14], as well as in studies related to glaucoma.

Despite these promising findings, several limitations warrant attention. The most significant limitation is the lack of a direct comparison between the device and a standard reference method, such as automated visual field measurement using a Humphrey device or frequency-doubled visual field measurement. Furthermore, the diagnostic sensitivity, specificity, predictive values, and ROC curve measures could not be calculated. Before clinical recommendation for widespread application of the device, validation studies comparing it to established visual field analyzers are needed [4][7][15].

These results indicate that the Cube Neuro-Optic Functional Testing Device is capable of providing new, clinically relevant information about peripheral visual information processing, beyond traditional visual acuity tests. The device was able to differentiate between healthy participants and those with ophthalmic and neurological conditions, and could become a readily available screening tool in both fields in the future. Multicenter studies involving larger samples, with direct comparisons to traditional visual field measurement techniques, are essential to determining diagnostic validity and clinical feasibility [4][10][15].

Other study investigates the effectiveness of a novel immersive device design that aims to overcome some of the accessibility limitations associated with traditional central visual field measurement [16]. The study of [17]. design provides a reliable means of conducting functional tests within primary (or community) healthcare facilities that distribute VR eye health monitoring and offers a more standardized cubic interface The system utilizes motion sensors and eye-tracking technology, minimizing environmental interference to achieve high-resolution data collection that meets clinical gold standards [18]. Furthermore, kinesthetic visual field measurement protocols are integrated into this spatial framework, producing a rapid visual field map with high space efficiency compared to a traditional Humphrey field analyzer [19, 20]. This platform employs adaptive spatial segmentation and real-time sensitivity mapping to significantly reduce testing time, while also mitigating the physical strain often associated with prolonged visual field testing [21, 22]. Several pilot evaluations of these virtual platforms demonstrate high diagnostic sensitivity across different patient populations, indicating strong agreement with the standard 24-2 visual field measurement criteria for both healthy eyes and those meeting the definition of glaucoma or other retinal diseases [23].

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However, due to significant variations in hardware specifications and software-generated stimulation protocols among the newer devices, further standardization of testing is needed before clinical applicability at points of care is possible [24, 25]. A solution to this problem lies in conducting future studies to calibrate the stimulation meter and illumination outputs at the population level, in order to produce standardized sensitivity estimates based on the Humphrey automated visual field measurement criterion [26]. Demonstrating this relationship is crucial to show that the device will be effective in other clinical settings where access to centralized, fixed diagnostic equipment is currently limited for population screening [27, 28].

Study Limitations

As an initial proof-of-concept investigation, this study operates with defined limitations. Primarily, the experimental design lacked a simultaneous, direct comparative arm utilizing a gold-standard device (e.g., automated static perimetry like the Humphrey Field Analyzer). Without this concurrent comparison, precise diagnostic metrics such as sensitivity, specificity, and Receiver Operating Characteristic (ROC) curves cannot yet be definitively calculated. Additionally, the cross-sectional methodology limits the ability to draw conclusions regarding how these response times fluctuate dynamically as the underlying diseases progress over time.

Conclusions and Future Research Directions

The Cubic Neuro-Visual Functional Screening Device offers an objective, digitally precise, and accessible methodology for evaluating peripheral visual processing. The clear identification of functional visual deficits in individuals with intact central acuity forcefully advocates for the integration of peripheral functional testing into standard eye care.

Future Directions

1. To advance this technology from a proof-of-concept stage to broad clinical implementation, a multi-tiered research approach is recommended:
2. Gold-Standard Validation: Conducting a large-scale, multi-center trial that directly compares the cubic device's response times against quantitative metrics from established FDT and HFA perimetry.

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3. Normative Database Development: Aggregating massive datasets to establish precise, age-stratified normative reaction times.
4. Longitudinal Tracking: Utilizing the device in a multi-year longitudinal study to determine if subtle changes in peripheral reaction time can serve as an early biomarker for the progression of neurodegenerative conditions before physical field loss is detectable.

Declarations

Intellectual Property and Conflicts of Interest

The core conceptual architecture and technological framework of the Cubic Neuro-Visual Functional Screening Device have been secured under formal intellectual property rights as of March 2026. Furthermore, the device and its underlying methodology were recognized and awarded first place at the Middle Technical University patent exhibition in April 2026. Beyond the stated intellectual property protections, the author declares no commercial licensing arrangements, corporate financial incentives, or other conflicts of interest that would inappropriately influence the data presented in this preliminary validation study.

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