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Integrating Virtual Reality Visual Perimetry Into Clinical Practice: A Review of Devices, Applications, and Limitations

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Introduction

Visual field testing has long been a cornerstone of glaucoma diagnosis, monitoring, and management. The evolution of perimetry, from the early Tangent screen formalized by Julius Hirschberg in the 1870s to modern standard automated perimetry (SAP) such as the Humphrey Visual Field Analyzer (HFA), has aimed to improve accuracy and accessibility. In the 1940s and 1950s, the Goldmann perimeter and Tübingen perimeter were developed, with the Goldmann retaining a limited but important role in specific clinical scenarios.[1] The Tübingen perimeter is now rarely used. By the 1980s, automated perimetry had become the standard, leveraging computational advances to reduce human involvement while preserving the spatial testing strategies introduced by earlier kinetic methods. Devices such as the Humphrey and Octopus perimeters became widely adopted and remain in clinical use today. Among these, the HFA is widely regarded as the gold standard for automated visual field testing.

Although the HFA is the gold standard for automated perimetry, it has well-known limitations. The device is expensive, requires substantial physical space, and requires a trained technician to operate. Importantly, many patients find the test uncomfortable or frustrating and often dread the experience. It is rare to encounter a patient who enjoys visual field testing, and poor tolerance can lead to unreliable results.[2–5] Nevertheless, perimetry remains a cornerstone of glaucoma care, offering functional insights not captured by structural imaging alone. Improving patient compliance and enhancing the test experience are therefore critical.

It is also well established that any factor impairing concentration can compromise the accuracy of the visual field results.[6] Many patients find the test mentally fatiguing, frustrating, and time-consuming, with few describing the experience positively. Common complaints include the prolonged duration, unpredictable endpoints, and the sense of being pushed to the limits of their visual capacity, often evoking a sense of failure. Physical discomforts are also common, including neck strain, difficulty maintaining posture, and suboptimal seating, despite manufacturer's efforts to improve ergonomics.

These challenges carry tangible clinical implications. When patients find visual field testing extremely unpleasant, they may even avoid coming for appointments altogether. This behaviour may be far more detrimental than poor adherence to treatment.[7] If perimetry itself becomes a barrier to care, clinicians must weigh its diagnostic value against its potential to undermine patient engagement and continuity of care.

For those reasons, there is a clear need for technology that is more patient-friendly—this is where virtual reality perimetry (VRP) offers promising potential. VRP is a novel approach that leverages virtual reality (VR) technology environments, typically accessed through lightweight, head-mounted displays. In the context of perimetry, this technology allows for visual field testing to be performed in a more natural, ergonomic position, often without the need for a dedicated dark room or large stationary equipment. As a result, VRP enhances patient comfort, portability, and accessibility. **Table 1**

Category	Advantage	Explanation
Physical Accessibility	Accommodates patients with limited mobility	VR headsets offer flexible positioning, making them ideal for those with neck stiffness, back pain, or those who are bedridden.
	Suitable for a range of body sizes	Patients who fall outside the size range recommended by standard perimeters (smaller or larger) can undergo testing more comfortably.
	Portability	Unlike conventional perimeters, VR systems are compact and portable, enabling testing in various settings.
Patient Comfort	Improved comfort and tolerance	Greater ergonomic flexibility (eliminating the need for a chinrest or rigid posture) helps reduce fatigue.
	Reduced claustrophobia	Head-mounted systems feel less enclosing than bowl perimeters.
	Enhanced patient experience	The immersive nature of VR may reduce anxiety and improve cooperation, particularly in anxious patients.
Clinical Usability	Tolerable in movement disorders	Head-tracking adjusts for tremors or involuntary movements, minimizing artifacts.
	Reduced rim artifact	Eliminates visual interference caused by the perimeter lens rim which can interfere with testing, especially when patients move or have deep-set eyes.
	Potential for home monitoring	Some VR platforms are being developed and tested for home use, which could allow for more frequent disease monitoring.
Technical and Language Features	Multilingual support	Some platforms have automated instructions in multiple languages (up to 25 on some platforms).
	Alternative visual backgrounds	Patients report that light-on-dark backgrounds are easier to interpret and cause less visual strain.
Operational and Cost Benefits	Cost-effectiveness	VRP systems are significantly less expensive to purchase and maintain. They also eliminate the need for large, table-based infrastructure.
	Enhanced patient engagement	The novelty effect may initially increase cooperation and reduce anxiety associated with testing.

Table 1. Advantages of VRP testing compared to SAP[2-4,8-13]; *courtesy of Abdullah Al-Ani, MD, PhD, Derek Waldner, MD, PhD, and Andrew Crichton, MD, FRCSC*

Abbreviations: VR: virtual reality; **VRP:** virtual reality perimetry.

highlights the advantages associated with VRP compared to SAP.

Physical Limitations

One of the main physical limitations that can affect SAP is patient positioning.[2,3] For example, patients with significant neck stiffness or kyphosis may have difficulties with placing their chin on the chinrest due to a forward head tilt, making it difficult for them to complete an HFA test. **Figure 1** shows a patient with a very stiff neck, making it nearly impossible to complete an HFA test. Another common scenario involves patients who are unable to sit up, such as bedridden patients, where the upright position is simply not feasible. VRP offers a particularly helpful alternative, especially during hospital consultations. Additionally, patients who are either too large to fit comfortably in the perimeter chair or too small to reach the chinrest often cannot be tested accurately or comfortably with traditional automated perimetry.

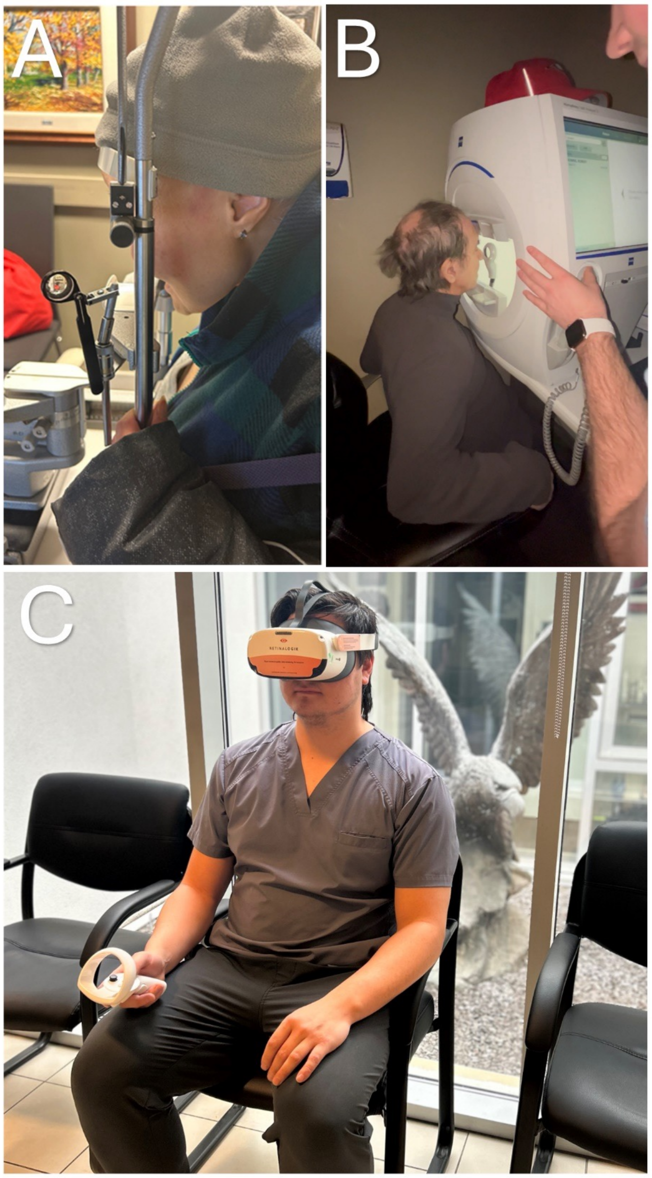

Figure 1. Comparison of patient positioning challenges in standard automated perimetry (SAP) versus virtual reality perimetry; *courtesy of Abdullah Al-Ani, MD, PhD, Derek Waldner, MD, PhD, and Andrew Crichton, MD, FRCSC*

A) A patient with significant neck stiffness is unable to achieve alignment at the chinrest due to a downward head posture. **B)** A patient with ankylosing spondylitis experiences great difficulty bending at the hips to position appropriately for SAP. **C)** A participant using a virtual reality headset is able to undergo visual field testing in a relaxed and more comfortable posture.

Beyond these extreme examples of physical limitations, there are broader comfort issues that affect many patients.[2,4] Back pain, hip stiffness, and general difficulty maintaining posture can make prolonged sitting uncomfortable. As mentioned earlier, anything that reduces comfort can affect concentration and, hence, compromise test accuracy. One of the advantages of VR-based perimetry is that it allows the test to be conducted in whichever position is most comfortable for the patient.

Movement Disorders

Movement disorders represent a separate but important challenge. In patients with conditions such as tremor or dystonia, constant head movements can lead to test artifacts, interruptions, and inaccuracies when using traditional perimetry. In contrast, with a VR headset, the display moves with the patient's head, reducing the impact of involuntary motion on test quality.

Rim Artifact

A common issue encountered with the HFA is the "rim artifact," which occurs when a patient unintentionally pulls back from the machine during testing, which brings the rim of the trial lens into the field of vision.[14] This can produce artificial peripheral defects that may be mistaken for pathology. Although lid artifacts can still occur, regardless of the device used, eliminating the rim artifact helps in confirming whether a defect is genuine. **Figure 2** shows examples of rim artifact.

Claustrophobia

Feelings of claustrophobia are a commonly reported concern among patients who undergo SAP testing. Some individuals describe the experience as feeling enclosed or trapped within the traditional bowl perimeter. In our glaucoma clinic, patients who have undergone VRP testing report feeling less confined and note a greater sense of space and comfort during the test.

Multilingual Support

Many VRP platforms offer multilingual support, enabling the test instructions to be delivered in multiple languages. This feature reduces reliance on interpreters and may improve patient understanding in diverse clinical settings. Devices such as the Retinalogik, VisuALL, and Vivid Vision Perimeter offer user-friendly

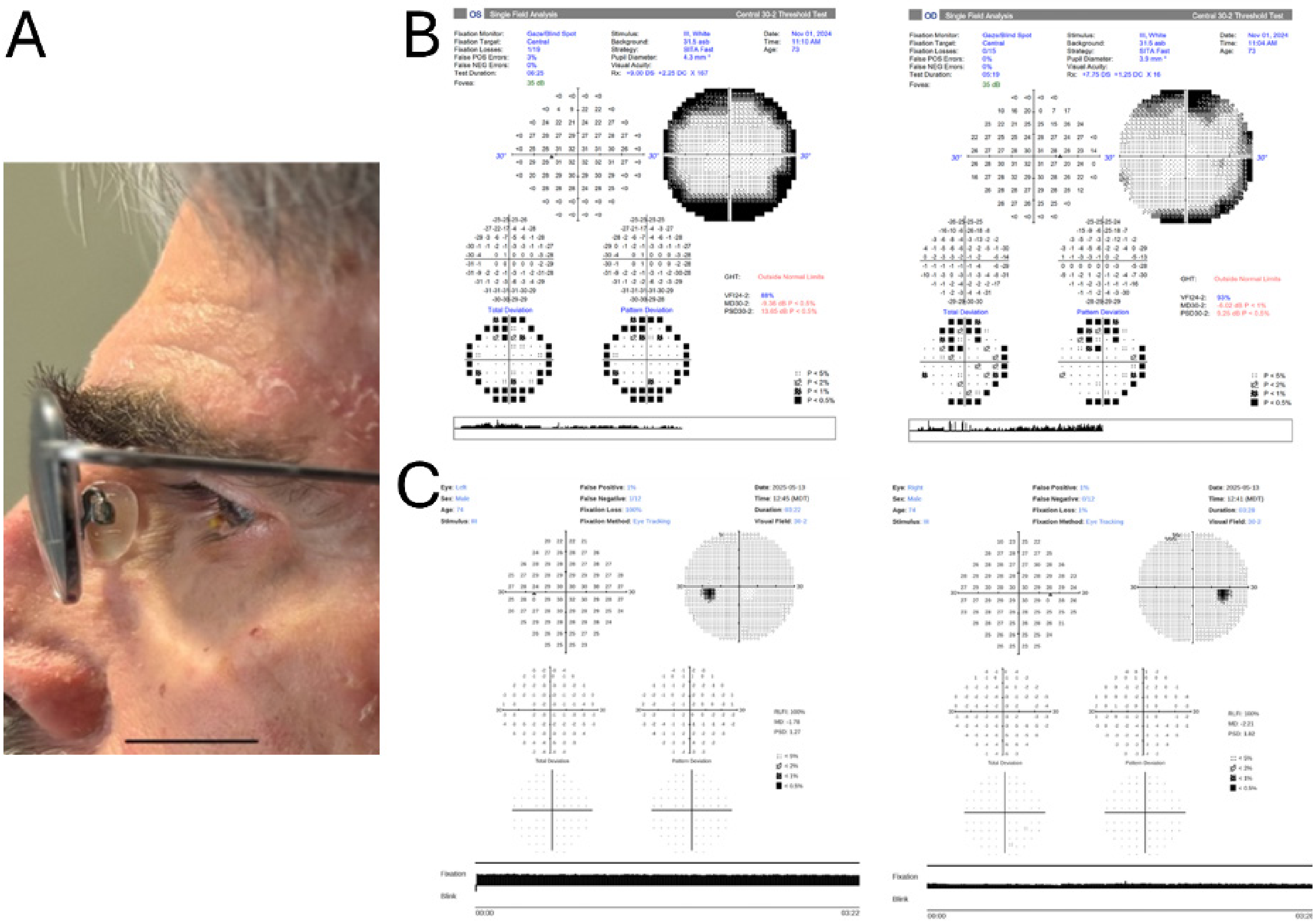

Figure 2. Illustration of rim artifact in standard automated perimetry and its elimination with virtual reality perimetry (VRP); *courtesy of Abdullah Al-Ani, MD, PhD, Derek Waldner, MD, PhD, and Andrew Crichton, MD, FRCSC*

A) Patient with deep-set eyes, anatomically predisposed to rim artifact due to the location of the trial lens. **B)** Visual field results from HFA 30-2 threshold testing showing a classic rim artifact, appearing as a dense peripheral field loss. **C)** The same patient underwent visual field testing using a VRP device, with no evidence of rim artifact.

interfaces that can be configured to support multiple languages, up to 25 in some cases.[5,13]

Background and Visual Environment

SAP typically uses white-on-white stimuli, which is the most validated and widely used method for detecting and monitoring visual field defects. However, VR perimetry platforms allow for flexibility in backgrounds and stimulus colours. Alternative combinations, such as blue-on-yellow or red-on-white, have been shown to improve sensitivity in detecting certain types of visual field defects in specific clinical scenarios.[15-17] In our clinical practice, many patients express a preference for a bright stimulus on a dark background, reporting less visual fatigue.

Novelty

One interesting factor reported by patients is the novelty of the VR experience. Many patients may find the VRP testing more engaging simply because it is different from the routine of traditional methods. While this could be a novelty effect rather than a sustained preference, our initial experience suggests that VRP testing is generally more well-received by patients. Whether this patient preference persists over time remains to be determined.

Cost

The cost difference between VR-based perimetry and conventional devices is considerable.[2] A VR unit may cost between $10,000 and $20,000 CAD if purchased outright, with some platforms offering an annual subscription model. In contrast, the total cost of a new HFA, including five years of annual maintenance, software upgrades, calibration, and certification, can range from $45,000 to $55,000 CAD. This cost gap, along with the option for yearly subscription-based access, significantly lowers the barrier to adoption, particularly for smaller clinics and low-resource settings.

Patient and Staff Comments

Feedback from both patients and staff has been overwhelmingly positive. Patients report increased comfort, ease of use, a preference for dark background displays, and the availability of multiple language options. Reminders and voice prompts during the test are also frequently appreciated by patients. Staff have also reported favourably on the adoption of this technology, particularly regarding the ease of setup, reduced patient resistance, and improved workflow efficiency. These points are further explored in **Table 2.**

Types of VRP Devices and Their Clinical Efficacy

Multiple VRP platforms have been developed over the past few years using a variety of hardware, algorithms, and luminance profiles. These vary from specialized configurations involving commercially available VR headsets to FDA-approved equipment with integrated eye tracking and custom threshold approach designs.[18]

VisuALL (Olleyes)

VisuALL is a commercially available VR head-mounted perimetry device supported by several published validation studies.[18] In a cohort of over 100 eyes, VisuALL demonstrated strong correlation with the HFA 24-2 SITA standard test across mean deviation (MD), sectoral sensitivity, and global indices.[9,18,19] One study reported no significant difference in diagnostic accuracy for detecting glaucoma between VisuALL and HFA (area under the curve [AUC] 0.98 versus 0.93, $p=0.06$).[9] In a small study involving 16 eyes, the VisuALL platform was found to be significantly faster than HFA, with a median difference of 69.3 seconds ($p<0.001$).[20] Overall, VisuALL's high diagnostic agreement with HFA and reduced test duration make it a promising tool, although preliminary studies suggested potential limitations in advanced glaucoma patients.[18]

Vivid Vision Perimetry (VVP); Suprathreshold

VVP is a suprathreshold perimetry software designed for use with commercially available VR headsets, such as the Oculus Go.[18] Two smaller studies, involving 24 and 36 eyes, respectively, demonstrated moderate to strong correlations with HFA MD values, with correlation coefficients ranging from $r=0.67$ to $r=0.86$ across different glaucoma severities.[21,22] While early data from the VVP Swift and VVP-10 protocols are promising, further validation studies are required to elucidate whether VVP is sufficiently sensitive to detect early-stage glaucoma.[18,21,22]

Toronto Portable Perimeter (TPP)

The TPP combines a smartphone with a VR headset and an associated mobile application using a ZEST-based thresholding strategy.[23,24] In a study of 150 eyes from 91 glaucoma patients, the TPP was compared to the HFA 24-2 SITA protocol and showed strong agreement in Bland-Altman analyses of MD, pattern standard deviation (PSD), visual field index, and test duration.[23] Differences between the devices were small, suggesting that while further validation studies are needed, the TPP is a promising platform for VR-based perimetry.

VirtualEye

The VirtualEye platform features a head-mounted OLED microdisplay with integrated eye tracking and offers both manual and visual grasp modes.[25] In the visual grasp mode, the direction of the patient's gaze is used to indicate stimulus detection, eliminating the need for manual clicking. In a study by Wroblewski and colleagues involving 62 participants (59 eyes tested in manual mode, 40 eyes tested in visual grasp mode) VirtualEye (in both modes) was compared with HFA 24-2 SITA. They found that the VirtualEye platform accurately detected large visual field defects. However, it demonstrated reduced sensitivity, particularly for high dB stimuli.[25] Despite this limitation, VirtualEye showed reasonable agreement with the HFA SITA protocol.

Advanced Vision Analyzer (AVA)

The AVA platform uses a liquid crystal head-mounted display with eye tracking and offers three testing strategies: Full Threshold, Elisar standard, and Elisar Fast.[26,27] Two studies with a combined sample size of 272 participants assessed the efficacy of the AVA platform against

Category	Advantage	Disadvatage
Patient Interaction	Patients report fewer complaints, and the test is generally better tolerated than SAP.	Some patients find the headset heavy, particularly during longer testing sessions.
	Built-in language support improves cooperation.	Difficulty accommodating patients with blurry vision, even with corrective lenses.
	Automated voice prompts reduce the need for continuous technician guidance, and reminders help patients in maintaining fixation during testing.	During head-levelling or calibration, patients may see a blank screen without any notification.
Workflow and Training	The VRP workflow is more streamlined than that of the HFA due to fewer instructions needed from the technician.	VR controller batteries drain quickly and need to be removed after use to preserve their charge.
	The system is easy to learn and operate with minimal training.	
Device Flexibility	The device is portable and can be used in multiple settings, and is not restricted to a specific testing room. Additionally, for patients who find the headset heavy, the test may be conducted while they are reclined.	

Table 2. Staff-reported Advantages and Limitations of Virtual Reality-Based Perimetry in Clinical Practice; *courtesy of Abdullah Al-Ani, MD, PhD, Derek Waldner, MD, PhD, and Andrew Crichton, MD, FRCSC*

Abbreviations: SAP: standard automated perimeters; **VR:** virtual reality; **VRP:** virtual reality perimetry.

the HFA 24-2 and 10-2 protocols.[26,28] These comparisons yielded moderate to high correlations for several parameters, including MD, PSD, and mean sensitivity.[18,26,28] Moreover, the AVA accurately differentiated glaucomatous from non-glaucomatous eyes, suggesting a promising role for this platform in both diagnosing and monitoring glaucoma patients.

Radius

The Radius platform features a lightweight headset with a 10 cd/m^2 background luminance and employs a proprietary RATA-standard threshold testing strategy.[18] In a study by Bradley et al., which included 100 adult glaucoma patients–half with suspect or mild glaucoma and half with moderate or severe glaucoma–Radius showed a strong correlation with the HFA 24-2 protocol (r=0.94 for MD) and shorter test duration (298 versus 341 seconds, respectively).[29] Additionally, the study showed excellent concordance in glaucoma staging (kappa=0.91-0.93), supporting the non-inferiority of Radius compared to HFA within the study population.[29]

Virtual Field on Oculus Go

Virtual Field is an FDA-approved VRP software that operates on the Oculus Go headset using a fast threshold strategy.[10] In a study by Phu and colleagues involving 95 eyes from 95 participants (41 controls and 54 with glaucoma) the platform demonstrated strong correlations with the HFA 24-2 SITA Standard test for MD (r=0.87) and PSD (r=0.94), with minimal bias observed in Bland-Altman analysis.[10] This study also showed that this VR platform had better reliability indices (lower fixation losses and false-positive rates) and significantly faster test completion times compared to HFA.[10]

RetinoLogik (RVF100)

Developed by the Canadian startup RetinoLogik, based in Calgary, the RVF100 is a VRP platform that operates on the Pico Neo 3 Pro Eye headset and features a background luminance of 10 cd/m^2. The RVF100 uses a proprietary thresholding algorithm that integrates statistical inference with age-correlated data. Early clinical adoption across several ophthalmology offices in Canada has been positive, with strong patient feedback. Preliminary usability surveys conducted by the authors (data not shown; manuscript under review) indicated that over 90% of participants preferred the RVF100 over traditional HFA testing. Several validation studies are currently underway globally to further evaluate the efficacy of the RVF100 in glaucoma care.

Limitations and Future Directions

While VRP holds tremendous promise in revolutionizing visual field testing, particularly by improving accessibility, patient comfort, and cost-effectiveness, the technology remains in its early stages compared to SAP and is subject to several limitations. In general, VRP platforms have higher test-retest variability than SAP, especially in pointwise sensitivity and global indices.[10] Additionally, because VRP is a relatively new technology, it relies on normative databases that may not be as robust or well-validated as those established in SAP.[10]

Hardware limitations also pose a challenge for VRP platforms. Their performance is at least partially limited by the quality of the headset hardware, which may restrict luminance ranges—even when paired with well-optimized software algorithms—potentially impacting VRP performance.[11,30] Furthermore, while several VRP platforms demonstrate a moderate to strong correlation with SAP for global indices and mean sensitivity, pointwise sensitivity correlations are often weaker. This raises concerns regarding discrepancies in fine-detailed virtual field mapping and its implications for clinical decision-making.[9] As VRP technology continues to evolve, particularly in the era of artificial intelligence, many of these limitations are expected to be addressed. We anticipate that with further development and validation, VRP has the potential to become a reliable and scalable adjunct, or even an alternative, to traditional SAP in selected clinical settings.

Summary

Despite all of the discussed advantages, VRP technologies remain in the early stages of development. Considering the current limitations and available literature, it remains uncertain whether VRP possesses sufficient reliability and sensitivity to replace SAP as the gold standard in glaucoma care. Validation studies are ongoing worldwide to further characterize the functionality, sensitivity, and reliability of VRP platforms in various patient populations. Given its flexibility in both testing posture and setting, VRP may be particularly beneficial for patients who are unable to undergo conventional perimetry. It may also serve as the only practical option in inpatient or low-resource environments.

At present, while VRP is not a replacement for SAP, the technology should be regarded as a valuable adjunct, especially in select populations. With ongoing advancements and further clinical validation, VRP holds the potential to become a powerful standalone tool for monitoring functional progression in patients with glaucoma.

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