Virtual Reality with Eye Tracking for Pediatric Ophthalmology:

a systematic review

Nikolaidou A. MD, MSc[1], Sandali A. MD(c)[1], Chatzidimitriou E. MD(c)[1], Pantelaki D. MD[1], Gianni T. MD, MSc, FEBO[1], Lamprogiannis L. MD, MSc, PhD, FEBOpth, FEBO-SP[2]

1: Aristotle University of Thessaloniki, Thessaloniki, Greece | 2: Ophthalmica Microsurgery Institute, Thessaloniki, Greece

INTRODUCTION

CONDENSED ABSTRACT

This review aims to investigate the current state of Eye Tracking (ET) technology integrated into Virtual Reality (VR) for pediatric ophthalmology. 22 relevant studies were incorporated and categorized into diagnosis, examination, treatment, and rehabilitation. Pediatric ophthalmology offers a promising landscape for the integration of ET within VR, with accelerated, quantifiable, and objective examination and diagnosis, and precise, real-time measurements, as well as facilitated compliance and adherence to therapy.

BACKGROUND

"Virtual Reality" (VR) consists of human interaction with a computer-3D-generated environment, receiving sensory information. The technology is optimal when integrating an eye-tracking (ET) system, meaning a system that converts eye movements into patterns. Although pediatric ophthalmology is especially accommodating in this regard, it has not been properly studied.

AIM

To investigate the utility of VR in the broader field of pediatric ophthalmology, zooming out of its pure surgical benefits to form a more spherical picture of the technology and its potential.

METHODOLOGY

SEARCH STRATEGY

Our systematic search encompassed the PubMed database, without imposing any time restrictions. The following search terms were used: "eye tracking", "eye tracker", "ophthalmology", "virtual reality", "children", "ocular motility", "strabismus", "squint", and "amblyopia".

INCLUSION/EXCLUSION CRITERIA

Three reviewers implemented the following Inclusion/Exclusion criteria, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Guidelines, with another reviewer responsible for settling any conflicts.

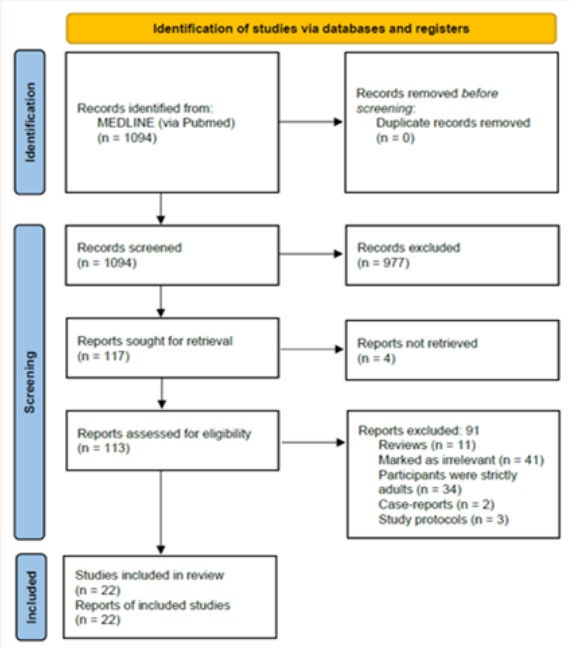
- All peer-reviewed studies and articles using ET in VR devices for diagnostic, therapeutic, or examination purposes for ophthalmic diseases were retrieved, with a focus on studies conducted in pediatric populations and written exclusively in English.
- Non-peer-reviewed literature, review articles and studies using only ET without VR devices, as well as articles with insufficient information on the technology used.

PROSPERO REGISTRY

The protocol for our review is registered under the following PROSPERO ID: CRD42023480298.

RESULTS

Our PRISMA Flowchart is as follows:



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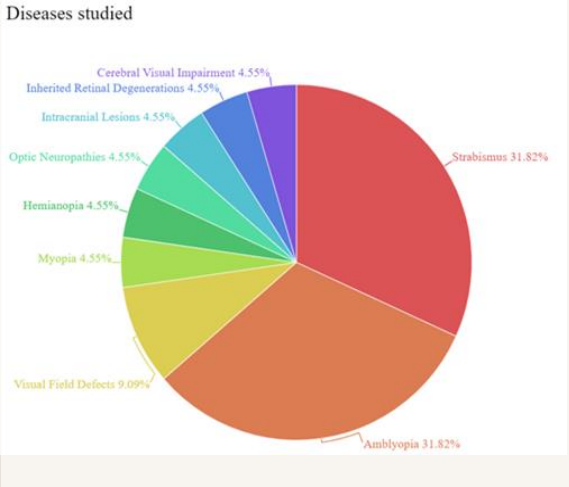
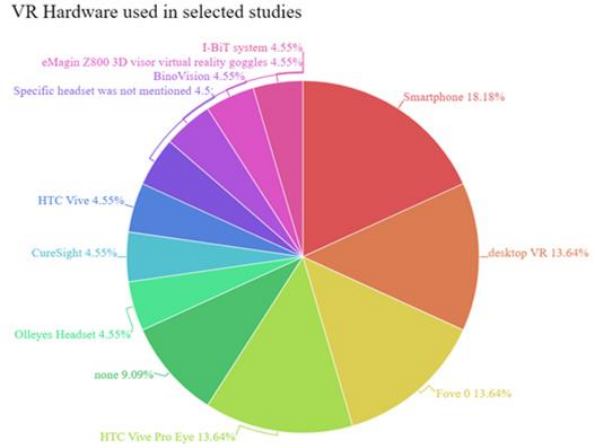
RESULTS (cont.)

STATISTICAL ANALYSIS

59.09% of included studies pertained to examination and/or diagnosis, 31.82% to therapy, and 9.09% to rehabilitation.
In the subsequent figures, we present statistical insights into the categorization of included articles, delineating their focus on specific diseases and the utilized VR hardware.





AMBLYOPIA

The use of VR as a therapy means for amblyopia is based on visual perceptual training, a concept defined as performance enhancement on a visual task as a result of visual experience through dichoptic stimulation, striving to replace traditional patching therapy. The consensus was that VR can be effectively used as a treatment option for amblyopia since it shows similar results to traditional methods and presents higher adherence rates and patient/parent preferences.

STRABISMUS

Articles pertaining to strabismus show the clearest relationship between VR and ET. Five articles tested VR with ET as a means of examination; they described their methods as highly accurate, efficient, and easy to use, as well as comparable to traditional methods of testing. Most of the studies showed agreement between their automated measurement of ocular angle deviation and the doctors' measurements, apart from one study which highlights a larger variation in their VR group. Two of the studies focused on rehabilitation and therapy. They mention improved stereopsis, eye position, fusion ability, central control ability and level of brain perception. The children's visual function was effectively better, and their eye position was better maintained.

MISCELLANEOUS DISEASES

Visual Field Defect: One study found that VR provides an appealing alternative examination for the young population. Another highlighted that VR allows for more reliable VF measurements in children, as fixation was maintained despite free range of movement.

Hemianopia: When VR with ET in the form of Visual Search Training was used, there was a decrease in search time during all search tasks, larger saccade amplitudes, decreased number of saccades, increased proportional number of saccades to the non-seeing side, and enhancement of the daily activities.

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RESULTS (cont.)

MISCELLANEOUS DISEASES (cont.)

Cerebral Visual Impairment: One cohort study aimed to objectively assess visual search performance in children with CVI, and found a lower success rate compared to healthy controls.

Inherited Retinal Degenerations: A VR orientation and mobility test could be used to measure functional vision and improved visually guided navigation after gene therapy in children with severe IRDs.

Optic Neuropathies: Detecting relative afferent pupillary defects using VR with ET, can be accurate, sensitive, easy to use, and fast compared to traditional methods, while remaining quantitative and objective.

Intracranial Lesions: an Eye Movement Pediatric Perimetry (EMPP) setup with integrated ET technology was used and marked as a feasible method for estimating the VF among children with intracranial lesions.

Myopia: VR, without implementing ET, was used to test refraction in participants. Binocular imbalance did not show a correlation with the unilateral eye refractive state and the visual acuity.

RISK OF BIAS ASSESSMENT

To guarantee a complete evaluation of research quality and include a wide variety of studies, we chose to employ the ROBINS-I instrument, the Risk of Bias 2 (RoB 2) tool, the Joanna Briggs Institute (JBI) Checklist for Diagnostic Test Accuracy Studies, and the Newcastle-Ottawa Scale (NOS). For results, please scan the appropriate QR code below.

DISCUSSION

Despite the limitations of our research, our findings indicate that incorporating VR and ET into standard pediatric ophthalmological practice shows potential. Important advantages to consider are compliance with the medical procedure, comfort of the systems and their interactivity and game-like configuration.

The presented devices mostly consist of a wearable headset, with or without an adapted tracking system, which reduces errors despite deviations of the head up to a value.

One final point that needs to be addressed concerns the possible side effects of prolonged VR exposure. In most cases, VR offers a positive user experience which is related to improving the quality of life by representing realistic daily activities. However, it has been observed that time restrictions are required in the use of these systems in order to avoid symptoms of fatigue, dizziness or even vomiting.

CONCLUSION

Pediatric ophthalmology offers a promising landscape for integration of ET technology within VR, with accelerated, quantifiable and objective examination and diagnosis, and precise, real-time measurements that are crucial in children. VR is an engaging experience, easily applied in a pediatric setting and facilitating compliance during examination and adherence to therapy. It is anticipated that further exploration is required for the widespread utilization of ET in VR within pediatric ophthalmology.

CONTACT DETAILS

Anna Nikolaidou | e-mail: anniko744@gmail.com

Dimitra Pantelaki | e-mail: dimitra.pantelaki@gmail.com

RoB Results

References