# Understanding Eye-Tracking in Virtual Reality*

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Over the last decades, eye-tracking technology has become increasingly popular in cognitive science research, and has also moved into related domains such as interaction design and UX [1]. As phrased, *the eyes are the windows to the mind* [2], eye-tracking can be a very important tool for understanding both human behavior and cognition. Up until now, eye-tracking has primarily been used for post-hoc analysis of the interaction. However, recent developments in virtual reality (VR) hardware with embedded eye-tracking create tremendous opportunities for several domains, including human computer interaction. Not only can we now more easily analyze and use eye-gaze behavior as an interaction modality in real time, but eye-tracking in VR opens opportunities for conducting human subjects research in novel 3D digital environments, where participants interact with digital artifacts in ways that would be very difficult or even impossible to achieve in the physical world. Where the majority of cross-disciplinary research between artificial intelligence and cognitive science is phrased in terms of cognitively inspired AI, we believe that the use of VR embedded eye-tracking constitute a domain of cross-disciplinary interaction in the other direction, i.e., making use of AI in order to provide new insights into human cognition.

Various methods and tools for systematically measuring eye-gaze behaviors have been around for nearly a century. An increased use of eye-tracking technology for research has contributed to a corresponding increase in discussions around collection, analysis, and validation methods relating to these systems [3, 4, 5, 6, 7, 8, 9]. The primary focus of these discussions is on eye-tracking in traditional 2D stimulus and gaze tracking contexts. However, VR embedded eye-tracking differs from the majority of historical eye-tracking research, both in providing relatively unconstrained movement and stimulus presentation distances. As a result, there is a need for greater discussion around methods for implementation and validating VR based eye-tracking tools.

In the work we present here [10], we provide an introduction to the challenges of, and methods for, 3D gaze-tracking in VR with a focus on best practices for results validation and reporting. Specifically, first, we identify and define challenges and methods for collecting and analyzing 3D eye-tracking data in VR. Then, we introduce a validation pilot study with a focus

*8th International Workshop on Artificial Intelligence and Cognition, June 15–17, 2022, Örebro, Sweden*
*Funding of this project was provided through the Swedish Knowledge Foundation as a part of both the Recruitment and Strategic Knowledge Reinforcement initiative and within the Synergy Virtual Ergonomics (SVE) project (#20180167).
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on factors related to 3D gaze tracking. The pilot study provides both a reference data point for a common commercial hardware/software platform (HTC Vive Pro Eye) and illustrates the proposed methods. One outcome of this study was the observation that accuracy and precision of collected data may depend on stimulus distance, which has consequences for studies where stimuli is presented on varying distances. We also conclude that vergence is a potentially problematic basis for estimating gaze depth in VR and should be used with caution as the field move towards a more established method for 3D eye-tracking.

## References


[1] A. Schall, J. Romano Bergstrom, Eye Tracking in User Experience Design, Eye Tracking in User Experience Design (2014) 1–374. doi:10.1016/C2012-0-06867-6.

[2] S. Khalid, J. C. Deska, K. Hugenberg, The Eyes Are the Windows to the Mind: Direct Eye Gaze Triggers the Ascription of Others' Minds, Personality and Social Psychology Bulletin 42 (2016) 1666–1677. doi:10.1177/0146167216669124.

[3] B. T. Carter, S. G. Luke, Best practices in eye tracking research, International Journal of Psychophysiology (2020). URL: https://doi.org/10.1016/j.ijpsycho.2020.05.010. doi:10.1016/j.ijpsycho.2020.05.010.

[4] A. M. Feit, S. Williams, A. Toledo, A. Paradiso, H. Kulkarni, S. Kane, M. R. Morris, Toward everyday gaze input: Accuracy and precision of eye tracking and implications for design, in: Conference on Human Factors in Computing Systems - Proceedings, volume 2017-May, 2017, pp. 1118–1130. URL: http://dx.doi.org/10.1145/3025453.3025599. doi:10.1145/3025453.3025599.

[5] R. S. Hessels, D. C. Niehorster, M. Nyström, R. Andersson, I. T. Hooge, Is the eye-movement field confused about fixations and saccades? A survey among 124 researchers, Royal Society Open Science 5 (2018) 180502. URL: https://royalsocietypublishing.org/doi/10.1098/rsos.180502. doi:10.1098/rsos.180502.

[6] J. Johnsson, R. Matos, Tobii ® Technology Accuracy and precision test method for remote eye trackers TestSpecification, Technical Report, Tobii Technology, 2011. URL: www.tobii.com.

[7] R. Kothari, Z. Yang, C. Kanan, R. Bailey, J. B. Pelz, G. J. Diaz, Gaze-in-wild: A dataset for studying eye and head coordination in everyday activities, Scientific Reports 10 (2020) 1–18. doi:10.1038/s41598-020-59251-5. arXiv:1905.13146.

[8] D. C. Niehorster, T. Santini, R. S. Hessels, I. T. Hooge, E. Kasneci, M. Nyström, The impact of slippage on the data quality of head-worn eye trackers, Behavior Research Methods (2020) 1–21. doi:10.3758/s13428-019-01307-0.

[9] J. L. Orquin, K. Holmqvist, Threats to the validity of eye-movement research in psychology, Behavior Research Methods 50 (2018) 1645–1656. doi:10.3758/s13428-017-0998-z.

[10] M. Lamb, M. Brundin, E. P. Luque, E. Billing, Eye-Tracking Beyond Peripersonal Space in Virtual Reality : Validation and Best Practices, Front. Virtual Real. 3 (2022) 1–19. doi:10.3389/frvir.2022.864653.