More Than Input: Using the Gaze-Psychology Link for More Accessible Augmented Reality

Alessandra Luz*
School of Computer Science, University of Waterloo
Canada
alessandra.luzlam@uwaterloo.ca

Johann Wentzel*
School of Computer Science, University of Waterloo
Canada
jdwentze@uwaterloo.ca

ABSTRACT

Eye tracking is a prominent area of HCI research, bolstered further by the inclusion of eye-tracked input in recent consumer mixed-reality products. The strong link between oculomotor behaviour and user psychology enables accessibility research opportunities which take advantage of eye-tracked interfaces for outcomes other than explicit input. We present potential augmented reality (AR) accessibility research directions which take advantage of this psychological link between eye movement and underlying psychology, and discuss our early work in the area.

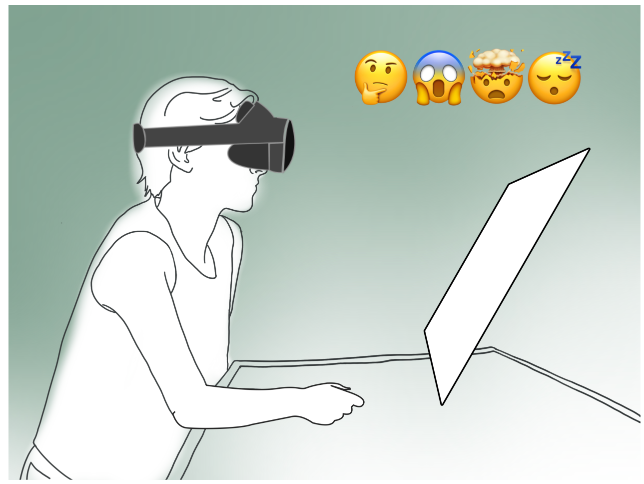

Figure 1: A user wearing a Quest Pro, using an AR application. The application makes use of eye tracking to infer the user's cognitive state, dynamically tailoring it to enhance cognitive accessibility.

1 EYE TRACKING AND PSYCHOLOGY

Eye-tracked mixed-reality headsets like the Apple Vision Pro and the Meta Quest Pro have pushed eye tracking into the mainstream. As of writing, consumer mixed reality (XR) products typically use eye tracking for two main purposes. First, the Vision Pro combines eye gaze and finger pinch [11, 12] as its primary mode of input. Second, social XR apps like VRChat can use eye gaze data for accurate gaze representation and eye contact in avatars [1]. These mechanisms typically take in positional pupil data as input, and produce either a raycast or an avatar motion as an output. However, the storied link between gaze and underlying human psychology can enable research directions above and beyond explicit positional input.

Traditionally, HCI has focused on eye-tracking within the realm of *explicit* input – positional data to be used for interaction or movement tracking. During a systematic review, Vasseur et al. [13] found that most eye tracking studies were traditionally run with desktop setups and recommended expanding eye-tracking HCI into new metrics, analyses, and devices.

The field of psychophysiology has pioneered the use of observable physical data to reveal human cognitive processes. Oculomotor movements and characteristics, alongside other metrics like heartbeat, brain waves, and hormonal changes, have been used to make conclusions about user behaviour and cognitive state. Observable cognitive behaviour can include both purposeful (conscious) and impulsive (unconscious) states [3]. Moreover, measurable cognition can also include generally personal phenomena like learning, reflecting, emotion, and memory. Gaze data can predict cognitive states like fatigue, attention, distraction, and mind wandering [9]. In addition to pupil dilations and blink rate predicting user confusion with 61% accuracy [5], pupil size has also been linked with emotions like sadness, fear, anger, or stress, as well as increased cognitive load [2].

Several of these papers serve the role of establishing eye-tracking as a less-intrusive (albeit lower-fidelity) form of brain-computer interface (BCI). Traditionally, BCIs are implanted inside the brain or placed on the scalp. However, Lech et al. [7] use eye tracking to make inferences about brain activity without the need to directly track signals from the brain. CyberEye, their implementation, used pupil dilation and gaze position to track attention or interaction in disorders of consciousness, and even predict memory performance in people with neurological diseases or injuries.

Fundamentally, the link between eye behavior and user psychology allows eye-tracking to function similarly to a BCI for some use cases. Unlike a BCI, eye-tracking hardware is more easily mass-distributed (thanks to recent XR headsets), less invasive than brain implants, and simpler to set up than in-lab instrumented headpieces.

Research Opportunities

Previous work demonstrating the link between cognition and gaze dynamics reveals several opportunities for AR interfaces that adapt to the user's individual cognitive state, providing accommodations that fit each user's needs. Future research can use eye tracking to increase the cognitive accessibility of augmented spaces, examples of which we provide below.

*Both authors contributed equally to this work.

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Eye tracking data, and its link to user engagement, could be used to improve cognitive accessibility within AR content. For example, using eye tracking within immersive educational content could reveal individual difficulties associated with learning and recall. If distraction is an issue, eye tracking analytics could then reveal possible distracting or challenging elements within the scene.

Similarly, eye tracking can reveal cognitive phenomena in people that might have a hard time self-reporting them. For example, children or people with verbal disorders may have a hard time self-reporting lack of attention, cognitive load, or other traditionally qualitative measures. However, using gaze data as a way to capture those measures might allow those same insights to be captured without the need for difficult questionnaires.

Immersive content, like that in virtual reality or spatial augmented reality, could cause stress, anxiety, or even fear in unprepared users. Considering that gaze data can identify emotional reactions like sadness, fear, or anger [2], understanding gaze behaviour could give valuable insights with regard to how an immersive experience could be stressful or challenging.

2 CURRENT RESEARCH

Eye tracking, as well as the implicit streams of input it enables, can be utilized to create more accessible and inclusive spaces. Accessibility is a wide spectrum, and using this implicit stream of input for AR can make direct forward impact in addressing permanent, temporary, and even situational impairments in people within real-world spaces. Our group has several examples of research dedicated to understanding gaze dynamics and using XR technologies to make spaces more inclusive.

Gaze for Identifying Intermittent Exotropia

Intermittent exotropia (IXT) is a type of strabismus (an eye disorder in which eyes do not line up in the same direction), which manifests with one eye moving outwards in irregular intervals [10]. Specific conditions such as low states of attention [10], sunlight [6, 14], and panoramic viewing [14] are known to induce eye deviations on people who have IXT. Our lab is working on a solution that can elicit this eye deviation in toddlers and children without external optometry tools or adult intervention, and measure the eye deviation angle using the eye tracking found in current smartphones.

More Accessible XR and Social Media

Collecting and evaluating gaze data for XR accessibility is part of a larger XR accessibility research agenda within our group. In addition to understanding other forms of context within XR motor accessibility [15, 16], ongoing work in our group explores the use of gaze tracking to evaluate engagement within social media videos.

Gaze for Accessible VR Locomotion

Our lab is developing and testing methods for traversing a VR scene using only eye gaze plus one additional button. Previous work demonstrates various methods including head gaze [8] or EEG [4], but do not directly compare eye- and head-gaze. We are planning to conduct this as an accessibility study involving participants with limited mobility.

3 AUTHORS

Alessandra Luz is a PhD candidate at the University of Waterloo. Her research focuses on bringing solutions to overlooked health, education and accessibility issues through the use of off-the-shelf technology used by the general population. Her thesis seeks to aid diagnostics and treatment of an oculomotor disorder. She completed multiple research projects with focus on eye tracking, systematic reviews, as well as collaborations with Huawei and Autodesk.

Johann Wentzel is a PhD candidate at the University of Waterloo, whose PhD research focuses on using user context and multi-modal input remapping techniques to make XR applications more accessible for people with mobility limitations. Johann has conducted eye tracking research at Meta Reality Labs, as well as XR accessibility research internships with Microsoft Research.

Alessandra and Johann are members of the Expressive Input & Interaction Lab, part of the Waterloo HCI Lab[1].

REFERENCES

[1] [n. d.]. OSC Eye Tracking. https://docs.vrchat.com/docs/osc-eye-tracking

[2] John T Cacioppo, Louis G Tassinary, and Gary Berntson. 2007. *Handbook of psychophysiology*. Cambridge university press.

[3] John F. Kihlstrom. 2018. *Unconscious Cognition*. Elsevier. https://doi.org/10.1016/B978-0-12-809324-5.21860-9

[4] Jinwook Kim, Hyunyoung Jang, Dooyoung Kim, and Jeongmi Lee. 2023. Exploration of the Virtual Reality Teleportation Methods Using Hand-Tracking, Eye-Tracking, and EEG. *International Journal of Human–Computer Interaction* 39, 20 (Dec. 2023), 4112–4125. https://doi.org/10.1080/10447318.2022.2109248

[5] Sébastien Lallé, Cristina Conati, and Giuseppe Carenini. [n. d.]. Predicting Confusion in Information Visualization from Eye Tracking and Interaction Data. ([n. d.]), 7.

[6] Judith B. Lavrich. 2015. Intermittent exotropia: continued controversies and current management. *Current Opinion in Ophthalmology* 26, 5 (July 2015), 375. https://doi.org/10.1097/ICU.0000000000000188

[7] Michał Lech, Andrzej Czyżewski, and Michał T. Kucewicz. 2021. CyberEye: New Eye-Tracking Interfaces for Assessment and Modulation of Cognitive Functions beyond the Brain. *Sensors* 21, 2222 (Jan. 2021), 7605. https://doi.org/10.3390/s21227605 Citation Key: lechCyberEyeNewEyeTracking2021.

[8] Andreas Linn. 2017. *Gaze Teleportation in Virtual Reality*. https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-216585

[9] Simon P Liversedge and John M Findlay. 2000. Saccadic eye movements and cognition. *Trends in cognitive sciences* 4, 1 (2000), 6–14.

[10] Yi Pang, Lawrence Gnanaraj, Jessica Gayleard, Genie Han, and Sarah R. Hatt. 2021. Interventions for intermittent exotropia. *The Cochrane Database of Systematic Reviews* 9, 9 (Sep 2021), CD003737. https://doi.org/10.1002/14651858.CD003737.pub4

[11] Ken Pfeuffer. 2024. Design Principles & Issues for Gaze and Pinch Interaction. https://medium.com/@ken.pfeuffer/design-principles-issues-for-gaze-and-pinch-interaction-a95e251169ae

[12] Ken Pfeuffer, Lukas Mecke, Sarah Delgado Rodriguez, Mariam Hassib, Hannah Maier, and Florian Alt. 2020. Empirical Evaluation of Gaze-enhanced Menus in Virtual Reality. In *Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology (VRST '20)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3385956.3418962

[13] Aurélie Vasseur, Mario Passalacqua, Sylvain Sénécal, and Pierre-Majorique Léger. 2023. The Use of Eye-tracking in Information Systems Research: A Literature Review of the Last Decade. *AIS Transactions on Human-Computer Interaction* 15, 3 (Sept. 2023), 292–321. https://doi.org/10.17705/1thci.00192 Citation Key: vasseurUseEyetrackingInformation2023.

[14] Frederick M. Wang and Gabriele Chryssanthou. 1988. Monocular Eye Closure in Intermittent Exotropia. *Archives of Ophthalmology* 106, 7 (July 1988), 941–942. https://doi.org/10.1001/archopht.1988.01060140087030

[15] Johann Wentzel. 2023. Bring-Your-Own Input: Context-Aware Multi-Modal Input for More Accessible Virtual Reality. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–5. https://doi.org/10.1145/3544549.3577056

[16] Johann Wentzel, Sasa Junuzovic, James Devine, John Porter, and Martez Mott. 2022. Understanding How People with Limited Mobility Use Multi-Modal Input. In *CHI Conference on Human Factors in Computing Systems*. ACM, New Orleans LA USA, 1–17. https://doi.org/10.1145/3491102.3517458

[1] http://hci.cs.uwaterloo.ca