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GazeDrift: A Balloon-Popping Serious Game for Eye Tracking Troubleshooting in VR

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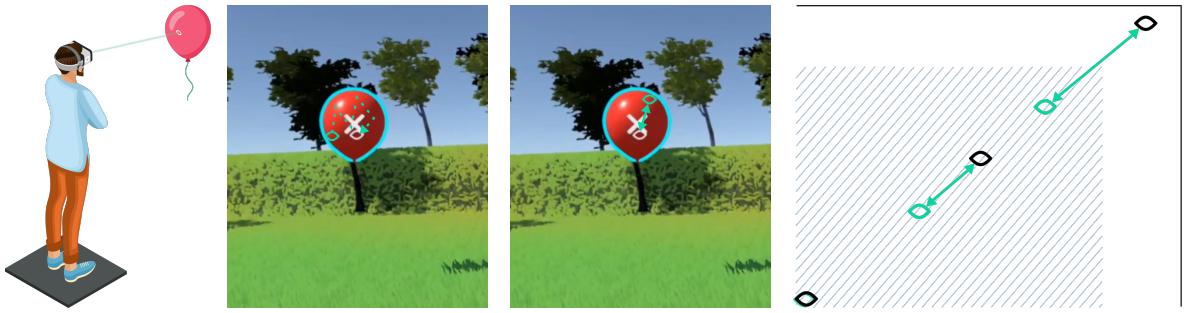

(a) Game setup. (b) Jitter noise. (c) Systematic shift. (d) Reduced peripheral accuracy.

Figure 1: GazeDrift teaches eye tracking challenges through balloon-popping gameplay: (a) shows the VR setup, while (b - d) demonstrate various gaze interaction artefacts addressed in the game.

Abstract

Eye tracking is integral to the user experience in modern extended reality (XR) headsets; however, practical deployment is frequently hindered by calibration drift, signal jitter, and the Midas touch problem. Non-expert users often lack the mental models required to distinguish between system inaccuracies and behavioural errors, complicating the troubleshooting process. To address this, we present GazeDrift, a virtual reality (VR) serious game designed to educate users about the inherent limitations of eye tracking. Through a gamified balloon-popping task, the system isolates and simulates three specific error conditions: jitter, systematic shift, and reduced peripheral accuracy. By combining interactive tutorials, feedback-driven gameplay, and conceptual quizzes, GazeDrift provides a structured environment for users to develop an intuitive understanding of gaze interaction artefacts.

Index Terms: Gaze-based Interaction, Eye Tracking, Serious Games, Virtual Reality.

1 Introduction

Eye tracking is commonly regarded as an important input modality for natural, hands-free interaction with digital systems. This principle remains relevant, particularly with the integration of eye tracking into contemporary extended reality (XR) devices, which utilise gaze to enable intuitive user interaction [5]. Therefore, there is considerable scientific and commercial interest in establishing gaze as a primary interaction modality for XR environments. However, deploying eye tracking in XR still faces several limitations. In practice, accuracy is often lower than specified, and performance deteriorates over time due to calibration drift caused by headset movement, changes in lighting, or variations in eye geometry [1, 5]. Beyond reduced spatial accuracy, users encounter common interaction artefacts, including jitter and systematic gaze shifts, lower precision in the periphery, and the Midas touch problem (i.e., because the eyes are constantly active, it is difficult to distinguish exploratory gaze behaviour from gaze used to issue commands [4]). Taken together, these factors mean that current systems do not yet provide the reliability and predictability that users are accustomed to from hand-based input, which can hinder the adoption of gaze as an everyday interaction method [9].

To this end, we aim to help users without prior eye-tracking experience understand and debug eye-tracking issues in XR. Serious games offer a promising approach to this type of education; they are educational tools that use game mechanics to achieve specific learning goals and align with defined learning outcomes [6], complementing traditional instruction through immersive environments where abstract concepts become tangible and easier to understand [3]. Serious games can foster intrinsic motivation and support learning where concepts are applied in meaningful contexts [7], while immediate feedback and progressive difficulty promote iterative learning and sustained engagement [2].

In this work, we present a serious game **GazeDrift** that uses a balloon-popping task to teach users about three core eye-tracking challenges in virtual reality (VR): jitter and shift noise, reduced accuracy in the visual periphery, and the Midas touch problem. The game combines short tutorials, level-based progression, quizzes, and performance feedback to help users build both a basic understanding and practical intuition about these issues, aiming to improve their proficiency with gaze-based interaction in XR.

2 GazeDrift System Description

GazeDrift is an educational VR serious game to help non-expert users recognise and understand common eye-tracking problems by experiencing them in a controlled balloon-popping task with immediate visual feedback. The system consists of (i) an initial gaze accuracy test and gaze correction, (ii) interactive tutorials that introduce specific error types and mitigation strategies, and (iii) timed gameplay levels followed by short quizzes to reinforce concept understanding. We implemented GazeDrift in Unity 2022.3.40f1, using the XR Interaction Toolkit v3.0.3, and tested it on an HTC Vive XR Elite.

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2.1 Accuracy test and gaze correction

The game begins with a 3×3 gaze-accuracy test, in which targets appear sequentially, and the user fixates on each target until it disappears. This yields nine correspondences between the known *target positions* $\mathbf{p}_i = (x_i, y_i)^\top$ and the *measured positions* $\mathbf{m}_i = (u_i, v_i)^\top$ recorded during fixation. We then map $\mathbf{m}_i$ to $\mathbf{p}_i$, following the linear transformation approach described in [8], to generate corrected gaze points without any system errors.

We compute a 2×3 affine transform $\mathbf{M}$ such that a measured gaze point (u, v) is mapped to a corrected point $(\hat{x}, \hat{y})$:

$$\begin{bmatrix} \hat{x} \\ \hat{y} \end{bmatrix} = \mathbf{M} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & T_x \\ c & d & T_y \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}. \quad (1)$$

The six parameters $\{a, b, c, d, T_x, T_y\}$ are estimated via linear least squares over the nine calibration samples, producing a best-fit correction. Afterwards, the system can display both the unmodified and corrected gaze indicators, allowing users to directly observe the effect of gaze correction before entering the tutorials.

2.2 Simulated eye-tracking errors

To demonstrate how distinct eye-tracking issues affect interaction, GazeDrift simulates three types of errors (as illustrated in Figures 1b-1d). All simulations are applied on top of the corrected gaze point $\mathbf{g}_{\text{corr}}$ to generate the interaction gaze point $\mathbf{g}_{\text{sim}}$ used for target selection. We simulate **Jitter** by applying small, frame-to-frame fluctuations to the gaze direction (up to 1.0° of angular offset), causing the gaze cursor to appear unstable even during steady fixation. We simulate **Systematic Shift** by applying a fixed directional offset (e.g., a constant angular offset of $[-3, 4, 0]^\circ$) to the gaze direction, resulting in a stable displacement across the visual field. We simulate **Reduced Peripheral Accuracy** by applying a linear radial expansion with a maximum scaling offset of 0.4. This makes the gaze cursor increasingly *less accurate* the further the user looks away from the centre of view; this means that when the user looks near the middle, the cursor stays close to where they are looking, but as they look towards the edges, the cursor is deliberately pushed further away from the reference cursor; this makes it harder to pop balloons in the periphery than in central vision, matching the typical user experience of poorer eye-tracking performance near the edges. In addition, we simulate potential mitigation strategies for each error type, such as noise reduction to reduce jitter, offset calculation to compensate for systematic shifts, and calibration to improve peripheral accuracy.

2.3 Game Setup

After calibration, the game introduces each error type in a short tutorial that explains what the user should look for (e.g., the gap between indicators) and then lets them practise by popping balloons under that specific error condition. Gameplay then proceeds through timed levels (currently three), each enabling one error type that the user must identify and compensate for to pop balloons efficiently. To support learning and engagement, the scene contains multiple balloon types with different colours and score outcomes: red balloons act as standard targets, bonus and penalty balloons award fixed point changes (e.g., +10, +30, and -50), blue balloons are *Midas-touch* balloons that trigger with 200ms dwell time, and purple balloons are used to emphasise peripheral-accuracy challenges. During the peripheral tutorial/level, peripheral balloons can be configured to disappear when not viewed peripherally, encouraging users to experience how accuracy degrades towards the edges of the field of view. Additionally, the score decreases over time to create a sense of urgency and motivate efficient gaze-based target acquisition. After each level, users complete a short narrated quiz that asks them to identify the error type they experienced and answers recap questions derived from the tutorial content, supporting conceptual understanding beyond motor adaptation.

3 Conclusion and Future Work

GazeDrift is a serious game designed to help end users and non-experts practically identify and understand common gaze-based interaction errors in VR. The system targets troubleshooting and education by making typical error patterns observable through short tutorials, gameplay levels, and quizzes. By framing this learning in a playful balloon-popping task, GazeDrift aims to provide an engaging entry point for building intuition regarding gaze-based interaction. We focus on jitter, systematic shift, reduced peripheral accuracy, and the Midas touch problem because these issues are frequently encountered in practice and are widely discussed as limiting factors for robust interaction. Overall, this demo aims to initiate a conversation on how gaze interaction in XR can be made easier to use and troubleshoot for non-experts through lightweight, enjoyable training tools. Future work will include a controlled user study to evaluate usability, user acceptance, and educational effectiveness (e.g., whether users can better recognise error types and apply mitigation strategies after playing). We also plan to extend the game content and challenge structure to better reflect realistic conditions and longer-term learning, moving towards a more comprehensive educational tool for XR setups.

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