HCI - Project 2 - Report

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1 Introduction

Recently, immersive environments such as Virtual Reality (VR) and Augmented Reality (AR) have become increasingly popular for both entertainment and practical applications. As these technologies evolve, designers face new challenges in creating interfaces that allow users to efficiently explore and interact with detailed visual content. One recurring challenge in VR is *visual search*, which refers to the task of locating a specific object or piece of information within a visually complex scene. Visual search plays a critical role in domains such as gaming, education, data visualization, and remote collaboration, but can become difficult when users are confronted with dense or cluttered visual information.

In VR, traditional strategies such as moving closer to a display or using static flat panels can be slow and fatiguing, often requiring repeated head or body movement and increasing workload. This motivates interaction techniques that support efficient visual exploration while preserving spatial context and minimizing user effort.

This project addresses the challenge of optimizing visual search in VR by comparing three different image presentation techniques:

1. **Baseline (Flat Screen):** the visual content is displayed on a static, flat image plane positioned in front of the user (see Figure 4);

2. **Curved Screen:** the image is presented on a gently curved surface surrounding the user, aiming to improve peripheral visibility and reduce the need for large head movements during exploration (see Figure 5); and

3. **Tilt-Assisted Screen:** a novel technique in which the flat image plane dynamically tilts according to the user's head-gaze direction, such that the region being looked at moves closer to the user while the opposite side moves farther away (see Figure 6).

By evaluating these three techniques, this study seeks to understand how different image presentation and interaction strategies influence visual search performance, user comfort, and perceived workload in immersive environments. In particular, the work investigates whether dynamically adapting the viewing geometry, through curvature or gaze-based tilting, can improve search efficiency while maintaining spatial context. The findings aim to contribute to the design of more effective VR interfaces for tasks involving large or information-dense visual content.

2 Related Work

Visual search involves locating a target within visually dense content. In 2D interfaces, zooming and panning support detailed inspection but can fragment spatial context and increase navigation effort. In immersive environments, these challenges are amplified by wide fields of view and the physical effort of sustained head and body movement.

Prior work has explored magnification-based approaches in VR. Knaack et al. Knaack et al., 2019 showed that magnification can improve readability, and Yamamoto et al. Yamamoto et al., 2018 reported improved accuracy in detailed inspection tasks. However, lens and zoom techniques often require explicit view manipulation, which can interrupt global spatial understanding and add interaction effort.

To reduce manual input, head and gaze-based interaction techniques have been proposed. Zhang et al. Zhang et al., 2025 introduced HeadZoom for hands-free zooming and panning, while Pfeuffer et al. Pfeuffer et al., 2016 demonstrated gaze as a useful attention signal for faster interaction. While these approaches reduce manual control, they still rely on zooming or viewport manipulation and may disrupt spatial context.

Beyond input modality, prior work has shown that the geometric presentation of visual content itself influences performance and comfort. Studies on curved and panoramic displays indicate that moderate curvature can improve peripheral visibility, while excessive curvature can negatively affect pointing accuracy and increase physical effort due to additional upper-body movement Chauhan et al., 2025. These findings highlight a trade-off between spatial coverage and interaction efficiency when altering display geometry.

Recent research has further emphasized the importance of perceptual stability in head-mounted displays. Dynamic spatial distortion, where object shape or position changes relative to user motion, has been shown to disrupt perceptual consistency, leading to increased cognitive effort, reduced comfort, and slower interaction Chauhan et al., 2025. This suggests that dynamic geometric adaptations must be subtle and coherent with user motion in order to avoid negative perceptual effects.

Building on this body of work, the present study investigates geometry-based image presentation techniques that avoid magnification altogether. In addition to flat and gently curved image planes, we intro-

duce a novel *tilt-assisted screen* that dynamically tilts toward the user's head-gaze direction. By responding to user attention while preserving global spatial context, this approach aims to reduce physical effort during visual search without introducing perceptual instability.

Accordingly, this study compares three image presentation techniques: **baseline flat viewing**, **curved screen presentation**, and **tilt-assisted screen**, to evaluate their effects on visual search performance, user comfort, and perceived workload in immersive VR environments.

3 Research Question

Building on previous work in magnification, head-based control, and visual search support, this study explores whether dynamic image transformations can improve user performance and comfort during search tasks in immersive environments. Although previous approaches have focused on zooming, highlighting, or automated cues, the proposed tilt-assisted image plane offers a novel and subtle form of interaction that leverages natural head movement to emphasize areas of interest without disrupting spatial context.

"How do different image presentation techniques (flat, curved, and tilt-assisted) affect visual search performance, comfort, and perceived workload in complex VR scenes?"

4 Hypothesis

Based on prior work on visual search, display geometry, and attention-aware interaction in immersive environments, we formulate the following hypotheses:

H1: Participants using the **curved screen** will achieve shorter search times than in the baseline flat screen condition.

Curved and panoramic displays have been shown to improve peripheral visibility and reduce the need for large head and body movements during wide-field visual exploration, which may lead to faster target acquisition compared to flat displays.

H2: Participants using the **tilt-assisted screen** will report higher comfort and lower perceived workload than both the baseline and curved screen conditions.

Prior research suggests that zoom-based techniques and explicit view manipulation can increase physical and cognitive effort, while head- and gaze-based adaptations that respond to user attention can reduce interaction demands. By subtly adjusting viewing geometry without magnification, the tilt-assisted technique is expected to improve comfort while preserving spatial context.

H3: The **tilt-assisted screen** will be preferred overall by participants.

Studies on adaptive visual guidance and attention-aware interfaces indicate that techniques which reduce physical strain and feel more natural are often preferred by users, even when objective performance improvements are not immediately observed.

5 Prototype

The prototype was developed in **Unity** and implemented three experimental conditions: **baseline flat screen**, **curved screen**, and **tilt-assisted screen**. Across all conditions, participants performed the same visual search task to ensure that differences in performance and experience could be attributed to the interaction technique.

In all conditions, participants located and selected a red W embedded within dense 2D images displayed in VR (see Figure 3). Each technique used a different set of five images matched for visual complexity to prevent memorization effects.

In the **baseline condition**, the image was displayed on a static flat plane positioned in front of the user. In the **curved screen condition**, the image was mapped onto a gently curved surface surrounding the user's field of view to improve peripheral visibility and reduce movements. In the **tilt-assisted condition**, the image was displayed on a flat plane that dynamically tilted according to the user's head-gaze direction, bringing the region of interest closer to the user.

Each condition included a short practice trial to familiarize participants with the viewing behavior. Interaction across all conditions relied on **controller-based raycasting** for target selection, and task performance data, including search time, which was logged automatically.

5.1 Setup

The experiment was conducted using a standalone **Meta Quest 3** head-mounted display, with the VR application deployed directly to the headset. Participants stood in an open physical space to ensure safe movement during the experiment.

Interaction was performed using Meta Quest hand-held controllers with controller-based raycasting. Head tracking was used to capture viewpoint and head-gaze direction for the tilt-assisted condition. All system settings and interaction methods were identical across conditions; only the geometry and behavior of the image surface (flat, curved, or tilt-assisted) varied.

6 Experimental Plan

The user study was conducted to evaluate three interaction techniques, baseline viewing, curved screen, and tilt-assisted screen, in terms of visual search performance, comfort, and overall preference. The study follows a within-subjects design, with all participants experiencing each technique.

Procedure

1. **Introduction and Consent:** Participants are first welcomed and given an overview of the project, including its objectives, tasks, and expected duration. They are informed about their rights, data privacy, and the voluntary nature of participation. Before proceeding, participants sign an informed **consent form**.

2. **Equipment Setup:** After providing consent, participants are fitted with the VR headset and any required equipment. A brief explanation of the interaction method is provided to ensure participants understand how to perform the tasks.

3. **Testing Phase:** The study evaluates three different viewing techniques. To minimize order effects and reduce potential bias, the presentation order of the techniques is counterbalanced across participants.

   For each technique, the following steps are performed:

   (a) **Practice Round:** Participants complete a short practice task to familiarize themselves with the viewing technique and controls.

   (b) **Task Execution:** Participants perform the main task, which consists of identifying and pressing the red **W** on five different images.

   (c) **Post-Technique Questionnaire:** After completing the task, participants fill out a short **questionnaire** assessing comfort, ease of use, enjoyment, and perceived workload for the current technique.

4. **Final Evaluation:** After completing all three techniques, participants complete a final questionnaire comparing the techniques and indicating **which one they preferred overall**. They may also provide qualitative feedback about their experience.

Data Collection

For each trial, the system automatically recorded task performance data, including search time. Search time was defined as the duration between image presentation and correct target selection. All performance data were exported to CSV files for statistical analysis.

Subjective data were collected using online questionnaires. After each viewing technique, participants rated comfort, ease of use, enjoyment, and perceived workload. A final questionnaire collected overall preferences, comparative ratings between techniques, and self-reported motion sickness symptoms.

7 Results

This section reports the results of the user study, focusing on objective visual search performance and subjective user feedback. The experiment followed a within-subjects design with three viewing techniques. Because search time data did not meet normality assumptions, non-parametric statistical analyses were applied.

7.1 Search Time Performance

For each participant and viewing technique, search time was summarized using the median of the five recorded selection times. These per-participant medians were used for all statistical analyses.

A Friedman test was conducted to evaluate differences in search time between the three viewing techniques. The analysis revealed no significant effect of viewing technique on search time,

$$\chi^2(2) = 0.17,\ p = .92.$$

Rank distributions were similar across techniques, indicating no consistent ordering of performance between conditions. As the global test was not significant, no post-hoc pairwise comparisons were performed.

7.2 Search Time Variability

Figure 1 illustrates the distribution of per-participant median search times for each viewing technique. The baseline condition shows the smallest
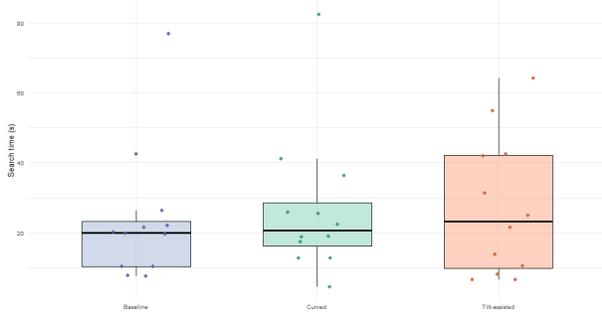
Figure 1: Distribution of median search times per technique. Each point represents the median search time of one participant.

interquartile range and fewer extreme values, indicating more consistent performance across participants.

The curved screen condition exhibits moderate variability, with a wider spread of completion times compared to the baseline. The tilt-assisted condition presents the largest interquartile range and higher maximum values, suggesting greater inter-participant variability.

These differences in variability indicate that participants adapted differently to the curved and tilt-assisted techniques, even though no statistically significant differences in central tendency were observed.

7.3 Subjective Experience

Subjective experience was assessed using post-condition questionnaires completed after each viewing technique. All items were rated on a 5-point Likert scale, where 1 indicates a strongly negative evaluation and 5 indicates a strongly positive evaluation. Questionnaire data were analyzed descriptively.

Across all techniques, baseline ratings were generally close to the neutral midpoint of the scale, reflecting a familiar but relatively unengaging interaction. Ratings for comfort, visual clarity, and ease of use showed limited variability in this condition.

The curved screen condition received similar ratings for visual clarity and ease of spotting the target, but comfort ratings were more dispersed. Several participants reported lower comfort ratings, suggesting increased physical effort during exploration.

The tilt-assisted condition received higher ratings for comfort and overall experience from many participants, with median ratings above the neutral midpoint. However, ratings for ease of spotting the target and perceived speed showed greater variability, indicating that the technique was not equally intuitive for all users.

Participant comments consistently aligned with the observed rating trends, particularly regarding comfort, physical effort, and perceived naturalness of the interaction.

7.4 Overall Preference

Overall preference was assessed using a final questionnaire completed after participants experienced all three viewing techniques.

When asked which technique they would prefer to use in the future, the tilt-assisted condition was selected by 58.3% of participants, followed by the baseline condition (25.0%) and the curved screen condition (16.7%).

Similarly, when asked which technique provided the best overall experience, the tilt-assisted condition was selected by 66.7% of participants, while both the baseline and curved screen conditions were selected by 16.7% of participants each.
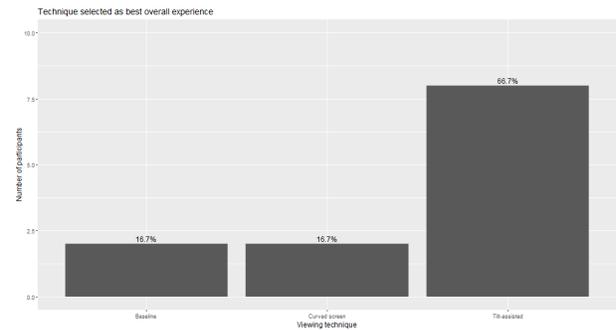

Figure 2: Number of participants selecting each viewing technique as providing the best overall experience.

8 Discussion

The results reveal a clear distinction between objective performance and subjective user experience, highlighting a common trade-off in immersive interface design between efficiency and comfort.

Regarding **H1**, which hypothesized that the curved screen would lead to faster visual search than the baseline flat screen, the results do not provide support. No significant differences in search time were observed between viewing techniques. This outcome may be explained by several factors. First, the image size was kept constant across all conditions, meaning that all techniques presented the same amount of visual information at a comparable scale. Second, the curvature used in the curved screen condition was intentionally moderate to avoid perceptual distortion and discomfort. While this supported visual stability, it may have limited the potential impact of cur-

vature on search performance. Additionally, the visual search task itself may have been insufficiently demanding to reveal performance differences, resulting in a ceiling effect where completion time was not sensitive to variations in viewing geometry.

An additional factor that may have contributed to the absence of significant performance differences is the use of controller-based raycasting for target selection. The recorded search time includes not only the visual search phase, but also the motor execution required to aim the controller and select the target. While changes in viewing geometry may facilitate visual exploration, they do not directly affect the precision or speed of ray-based pointing. As a result, performance differences related to visual search may have been masked by the motor component of the task.

H2 proposed that the tilt-assisted technique would improve comfort and reduce perceived workload compared to the baseline and curved conditions. Subjective ratings and participant comments partially support this hypothesis. The tilt-assisted technique was perceived as more comfortable and engaging, likely due to its ability to reduce perceived physical effort by dynamically adapting the image plane to the user's head-gaze direction. However, this dynamic behavior also introduced an additional layer of interaction that required adaptation.

The high variability and lower objective performance of the tilt-assisted technique can likely be attributed to its status as a novel interaction metaphor. Unlike the baseline, which mimics the ubiquitous experience of static image search (e.g., Where's Waldo books), or the curved screen, which shares a mental model with commercially available curved monitors and immersive cinema, the tilt-assisted plane has no direct analog in everyday life. Consequently, while participants could immediately apply lifelong habits to the first two conditions, the tilt-assisted technique required them to develop a new sense of coordination on the fly.

The baseline flat screen condition produced the most consistent search times, which is likely attributable to familiarity and predictability. Participants are highly accustomed to flat, static displays, enabling efficient visual search strategies with minimal learning. However, the lack of adaptive support in this condition may have required greater physical effort, such as repeated head movements, negatively affecting perceived comfort and engagement.

The curved screen condition showed intermediate performance and variability. While increased curvature can improve peripheral visibility, it may also introduce spatial distortion or require additional head movement during focused search tasks, potentially offsetting any performance benefits.

Regarding **H3**, the hypothesis that the tilt-assisted technique would be preferred overall was supported. A majority of participants selected the tilt-assisted condition as providing the best overall experience and as the technique they would prefer to use in the future. These preferences emphasize the importance of comfort, perceived naturalness, and reduced physical effort in immersive interaction, even in the absence of objective performance improvements.

The study initially intended to include miss rate as an additional objective performance metric. However, due to an issue with button detection in the Unity implementation, missed selections could not be reliably recorded and were therefore excluded from the analysis. Error-based measures such as miss rate may provide greater sensitivity in future studies, particularly for more demanding search tasks or under time pressure.

Overall, these findings suggest that moderate geometric adaptations alone may not be sufficient to improve visual search performance under relatively easy task conditions. However, adaptive techniques such as tilt-assisted viewing show strong potential for enhancing user comfort and engagement, especially in scenarios involving prolonged interaction or exploratory behavior.

9 Conclusion

This study investigated how different image presentation techniques—baseline flat screen, curved screen, and tilt-assisted screen—affect visual search performance and user experience in immersive VR environments.

Objective performance analysis showed no statistically significant differences in search time between techniques, leading to the rejection of H1. The baseline flat screen condition produced the most consistent performance, likely due to user familiarity and stable geometry. However, performance differences may have been limited by task difficulty, moderate geometric parameters, and the use of controller-based raycasting, which introduced a motor component into the measured search time.

Subjective results provided partial support for H2. While the tilt-assisted technique did not improve objective performance, it was perceived as more comfortable and less physically demanding than the other techniques. This suggests that adaptive viewing geometry can enhance user experience even when performance gains are not immediately observed.

H3 was supported, as the tilt-assisted technique

was preferred by a majority of participants and was rated as providing the best overall experience. These findings highlight a key trade-off in immersive interface design: techniques that maximize comfort and perceived naturalness may be favored by users despite slower or more variable performance.

Future work should explore longer exposure periods, more challenging visual search tasks, and alternative selection methods such as gaze-based interaction to better isolate visual search performance. Additionally, refining curvature and tilt parameters and incorporating error-based metrics, such as miss rates, may provide further insight into the effectiveness of adaptive image presentation techniques.

In conclusion, while performance appears tied to long-standing daily habits with flat and curved media, the preference for the tilt-assisted screen suggests that novelty and physical comfort are equally vital metrics for the future of immersive interface design.

References

Chauhan, Y., Zhu, C., Yang, Z., & Zhang, Y. (2025). Effects of dynamic spatial distortion on user comfort, interaction efficiency, and immersion in virtual environments. *Displays*.

Harada, T., & Ohyama, S. (2021). Quantitative evaluation of visual guidance effects for 360-degree directions. *Journal of Imaging Science and Technology*, *65*(3), 30401–30412.

Knaack, M., Li, T., & Bruder, G. (2019). Improving readability of text in realistic virtual reality scenarios: Visual magnification without restricting user interactions. *Proceedings of the IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 183–192.

Pfeuffer, K., Mayer, B., Gehring, S., & Rukzio, E. (2016). Gaze+pinch: Hands-free yet precise interaction for mobile augmented reality. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2668–2679.

Warden, O., Zielasko, D., & Latoschik, M. E. (2023). The impact of imperfectly automated cues in an augmented reality head-mounted display on visual search performance. *Frontiers in Virtual Reality*, *4*, 1196858.

Yamamoto, T., Kudo, T., & Sato, K. (2018). Visual magnification interfaces for detailed inspection tasks in immersive environments. *International Journal of Human–Computer Interaction*, *34*(11), 1015–1027.

Zhang, K., Lee, H., & Lin, C. (2025). Headzoom: Hands-free zooming and panning for 2d image navigation using head motion. *Proceedings of the ACM Symposium on Spatial User Interaction (SUI)*.

A Appendix

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U  J  T  P  Q  C  V  O  D  H  D  S  P  C  I  N  A  W  Y  T
Y  Q  W  B  C  I  G  C  A  D  A  Q  R  D  C  H  N  Q  T  I
Z  G  T  K  S  E  D  W  F  A  C  H  W  H  J  F  E  B  L  S
N  F  K  G  U  B  A  W  D  H  Q  W  A  L  I  Y  R  D  E  U
X  L  I  P  O  G  V  D  C  B  X  B  A  C  D  M  Y  Q  E  H
B  V  F  J  I  L  K  B  U  Y  X  G  P  I  L  H  T  T  X  R
H  N  D  T  Z  K  T  E  X  F  M  I  S  T  X  D  R  Q  F  U
X  M  V  D  H  O  L  U  L  C  Q  Q  Z  Z  W  X  I  J  I  D
A  A  R  X  T  B  Z  W  T  C  A  G  T  N  M  O  R  P  D  M
Z  F  H  Q  I  F  H  D  D  V  K  Q  A  T  C  D  B  Z  N  B
B  P  E  H  B  F  D  N  J  Q  K  U  A  M  N  Y  S  O  D  H
E  X  A  Z  R  T  E  B  W  D  Z  O  V  Z  Z  M  P  Q  N  K
V  L  F  Y  X  Q  P  I  D  O  N  K  G  M  N  W  X  I  B  T
Q  Q  U  L  V  P  U  H  I  H  P  I  M  U  T  I  W  V  G  V
R  C  Z  N  U  K  B  Q  X  J  K  Y  L  Y  F  S  P  K  M  M
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Figure 3: Example of a visual search test used in the experiment.
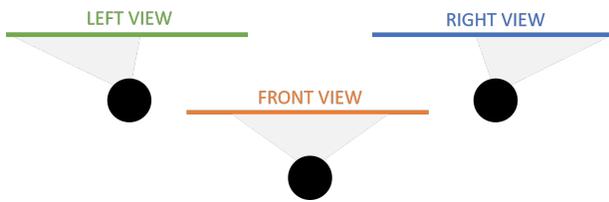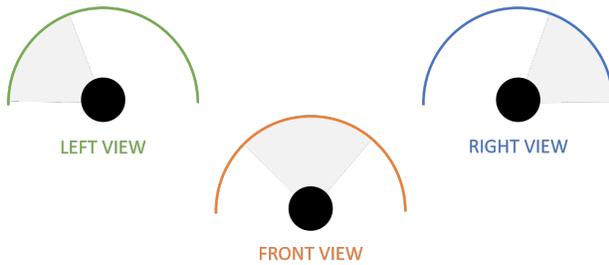

Figure 4: Baseline Technique

Figure 5: Curved Screen Technique

Figure 6: Tilt-Assisted Technique