User Experience Research Play Card in Augmented Reality: A sensemaking case study on designing Visibility and Modality

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***Abstract*— Despite the existence of high-level guidelines and frameworks in Human-Computer Interaction (HCI), there is a lack of specific user experience principles for designing augmented reality (AR). This paper proposed the creation of a series of user experience research (UXR) play cards aimed at providing UX practitioners concrete, AR-specific UX design based on The Point of view (POV) UXR playbook. Through the development of a series of 'Hidden Reality' and 'Modality' play cards, we propose a tool that not only enhances the design process but also enriches the overall AR experience for users, paving the way for more meaningful and engaging AR applications. At the heart of this process is the concept of sensemaking, a key method that clarifies the way forward, simplifies the upward journey of the UX's POV pyramid and offers profound insights into user needs and behaviours.**

Keywords*— *Augmented Reality, User Experience, Human Computer Interaction, HCI models

I. Introduction

In the evolving landscape of Human-Computer Interaction (HCI), the integration of augmented reality (AR) presents a unique set of challenges and opportunities for enhancing user experience (UX). Despite the comprehensive guidelines and frameworks established within HCI, there remains a notable gap in the development of specific UX principles tailored for AR applications [1]. This gap highlights the need for a more focused approach in crafting AR experiences that are not only immersive but also represent visibility [1] of real-world content and Modality [6], which are accessible to diverse end users. Addressing this need, this paper introduces the 'Hidden Reality' and 'Modality' concept of a set of User Experience Research (UXR) play cards for AR, drawing inspiration from the Point of View (POV) UXR playbook [2, 5]. Playbook's paper [2] introduced an innovative approach aiming to provide UX practitioners with specific UX principles, offering a structured methodology to navigate the complexities of AR design.

Sensemaking [3] is a methodological approach that addresses how people give meaning to their collective experiences. It is particularly relevant in complex and uncertain environments, where the traditional models of problem-solving and decision-making fall short. This idea is especially relevant for identifying the significant awareness of AR in HCI, where traditional straightforward methods of solving problems and making decisions don't always work. Sensemaking focuses on the importance of how individuals and groups interpret and construct their reality. This is key for helping organizations, design teams, and individuals find their way through unclear situations to reach a clear, shared understanding. By incorporating Sensemaking into the UX POV playbook, the paper aims to provide deep insights on 'Hidden Reality' and 'Modality' awareness in AR for researchers and designers. These insights help tackle important questions, pushing them towards better design thinking and applicable play cards. By highlighting AR's unique aspects like visibility and Modality, as well as considering the diverse needs of users, this paper seeks to close the existing gap. It lays the groundwork for creating AR experiences that are more engaging, inclusive, and intuitive.

The essence of these play cards in this paper lies in their ability to capture best practices, facilitating researchers and designers in answering critical questions that elevate them to higher levels of design thinking and application. By focusing on the unique aspects of AR, such as visibility and Modality, and considering the diverse needs of users, this paper endeavours to bridge the existing gap.

II. Literature Review

A. Augmented Reality

AR technology [7] has advanced significantly, enabling the superimposition of digital information onto the physical world in real-time. Augmented reality (AR) has been defined [10,11, 12] as mixing real-world scenes with virtual elements, like 3D objects, in real-time. This technology, explored by researchers

across different fields, enhances how we see and interact with our surroundings, aiming to make our experiences more immersive and informative. This immersive interaction bridges the gap between digital and physical realms, offering novel ways to engage with content. However, these advancements also bring to the forefront the complexity of designing user-centred experiences that are intuitive, accessible, and meaningful. Literature suggests [8,9] that while AR technologies have progressed, the development of UX principles tailored specifically for AR lags, emphasising the need for research that focuses on user-centric design principles in AR applications.

B. UX in AR

Research has increasingly recognised the importance of addressing specific UX challenges in AR, such as the seamless overlay [13] of virtual content on the real world, ensuring that digital augmentations enhance rather than detract from the user's engagement with their environment. Research explores the complexities of visibility [1] and Modality [14] in augmented reality (AR). They recommend AR designs that keep users aware of their real surroundings while adding virtual elements.

The innovation of User Experience Research (UXR) plays cards, inspired by the Point of View (POV) UXR playbook [2], marks a significant advancement in this field. This paper provides a structured yet flexible approach to tackling AR UX challenges, emphasizing the iterative refinement of AR experiences through user-centred design principles. The play cards, which address scenarios such as 'Hidden Reality' and various modalities of interaction (audio, tactile, etc.), reflect a deep understanding of the need for AR systems to be adaptable and sensitive to user needs.

C. Sensemaking

the application of Sensemaking within the AR design process highlights an evolving perspective on UX research, focusing on understanding user behaviours, preferences, and the cognitive processes involved in interacting with AR. This approach facilitates a more nuanced exploration of how AR can be optimized to support users in navigating and making sense of enhanced realities.

Overall, the existing literature highlights the critical role of UX in the development and adoption of AR technologies. By prioritising user-centred design and exploring innovative methodologies like UXR play cards [2], the field continues to evolve towards creating more meaningful, engaging, and accessible AR experiences. This body of work not only addresses the 'Hidden Reality' or ‘Modality’ challenge but also sets a foundation for future research to build upon, encouraging a broader exploration of how AR can transform user interactions across various domains.

III. METHODOLOGY

This section offers a detailed overview of the methodology adopted in this study, which is mentioned by the User Experience Research (UXR) playbook [2]. This innovative approach is centred around the development and application of play cards, designed to provide UXR practitioners with a comprehensive set of strategies and tools. The playbook cards play an important role in this methodology. Each card is designed to represent either a potential challenge or an opportunity for establishing a POV. The cards are dual sided: the front side outlines the issue, card type, and includes an insightful quote along with related cards, while the back side provides detailed guidance with ‘Best Practice’ on addressing the issue. This structure promotes a dynamic and adaptable use of the play cards, facilitating seamless transitions between levels as required by the research or design process.

Four levels: foundation, data collection, insight generation, and crafting a compelling UXR POV have been clearly defined in the UXR POV pyramid framework [2]. This structure symbolises a systematic approach, integrating various disciplines like technology and marketing, to achieve a cohesive and impactful research perspective.

To offer UXR practitioners a tangible toolkit in AR design, the playbook card approach enables the examination of specific AR UX issues, combining deep user understanding and ‘Best Practices’ guidance. This structured flexible framework also supports the UX team to iteratively refine AR experiences, ensuring they are not only immersive and engaging but also grounded in user-centric principles.

Crafting a compelling UXR Point of View (POV) in AR isn't a linear journey. It's a dynamic exploration through the complexities of user research, data analysis, and team collaboration, akin to scaling the multifaceted UXR POV Pyramid. In this paper, we used another specialised approach called Sensemaking [3] to identify the key UX issues for designing Augmented Reality. Sensemaking can illuminate the path forward, streamlining the ascent of the UXR POV pyramid and revealing deeper user understanding at every step. Sensemaking can be seen as the guide for the UXR POV Pyramid journey. It equips researchers and their teams with the skills to: Discern patterns and trends. By iteratively analysing research findings, user feedback, and market signals, sensemaking helps identify critical themes and connections. Bridge disciplinary divides: Different areas (design, research, marketing, technology, business etc.) bring unique perspectives to the table. ensuring all voices are heard and integrated into a balanced, holistic POV, represented by the different sides of the POV pyramid working in harmony. Embrace continuous learning: The iterative nature of Sensemaking encourages an openness to new information and feedback. This adaptability allows researchers to refine their POV as they progress through the pyramid, constantly incorporating new insights and perspectives. The iterative learning is represented in the arrows moving between the pyramid's levels.

Our team reviewed the existing AR features [4] together, AR examples, user feedback and research. Then identified the main theme – Hidden Reality and Modality awareness that could enhance the AR UX design. By working together across different areas like design, research, and technology, we make sure everyone's ideas are included. These cards help us look at user research in a way that informs how to improve AR visibility and other Modality channels and enhance AR UX design.

IV. AUGMENTED REALITY PLAY CARDS: VISIBILITY AND MODALITY

A. *Foundation AR features*

AR technology now has been designed for different users (e.g. vulnerable, disability, different culture background, ageing population). Sha's PhD [4] identified a series of AR user experience features listed below:

- Hidden Reality: Virtual content overlies or hides the real content, where the real content is not required to achieve users' goals.
- Modality-focus Augmentation: Virtual content can be provided in different modalities (such as visual, audio, vibration, etc.), depending on the users' goals.
- Instantaneous Augmentation: If the virtual content cannot be displayed promptly, then provide prompt and informative feedback to the users.
- Accurate Augmentation: The virtual content is displayed in the way that users would expect, given their goals.
- Layer-focus Augmentation: Where more than one piece of virtual content is required, these can be displayed in separate layers if that supports the users' goals.

Based on UXR POV pyramid framework [2], all these features could be seen as the foundational level of user experience because they set essential guidelines for designing inclusive AR technologies, ensuring broad accessibility and user empowerment. Instantaneous and Accurate Augmentation are largely dependent on the quality of the AR device, addressing the technical capabilities required to meet user expectations for prompt and precision. Layer-focus Augmentation is a complex question. It emphasises the one or multi-layer overlay of virtual content based on user needs, either increasing or decreasing it. This paper only focuses on the single-layer virtual content. Multiply-layer focus can be explored in future research. Therefore, the two major features: Hidden Reality and Modality are highlighted here.

B. *Hidden Reality Play Cards*

This paper takes an in-depth look at the impact of Hidden Reality and Modality awareness. The concept of HR emphasises that the virtual content will hide or obscure some of the real content and users cannot see through. Sometimes, we must remove the existing AR/VR device and let the user see real content clearly. However, repeatedly putting on and taking off the device will greatly affect the user experience. Based on the UXR Playbook template, we create a series of play cards to follow when we try to address the Hidden Reality issue. Designing the virtual content needs to consider what will be hidden as much as what will be shown. Although users should benefit from seeing the virtual content, it should not obscure the meaningful real content that provides important surrounding information.

Based on the awareness of Hidden Reality, this paper lists a series of play cards including (see Fig. 1):

- Diminishing Virtual Content (Fig. 2)
- Separating Virtual Content (Fig. 3)
- Transparency (Fig. 4)
- Closer or Distancing (Fig. 5)
- Drag and Drop (Fig. 6)

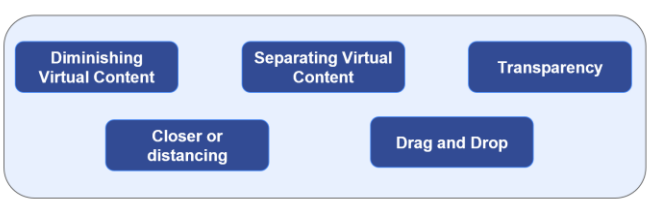

Fig. 1: Hidden Reality awareness play cards within UXR-AR.

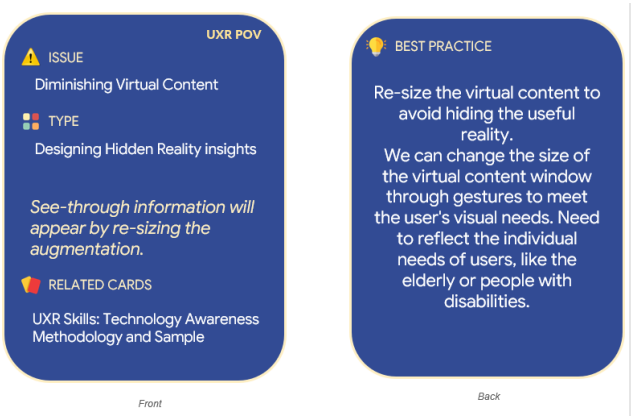

Fig. 2: Diminishing Virtual Content play cards in Hidden Reality awareness.

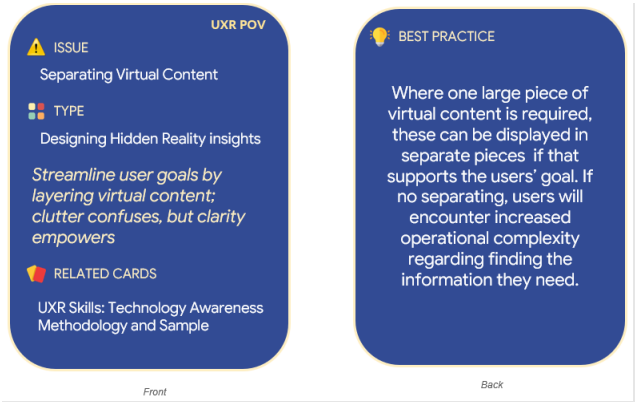

Fig. 3: Separating Virtual Content play cards in Hidden Reality awareness.

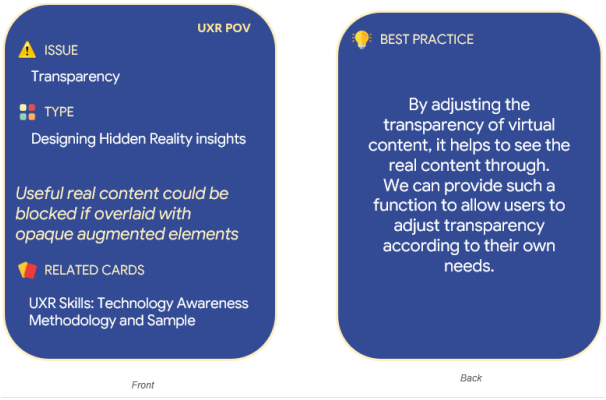

Fig. 4: Transparency play cards in Hidden Reality awareness.

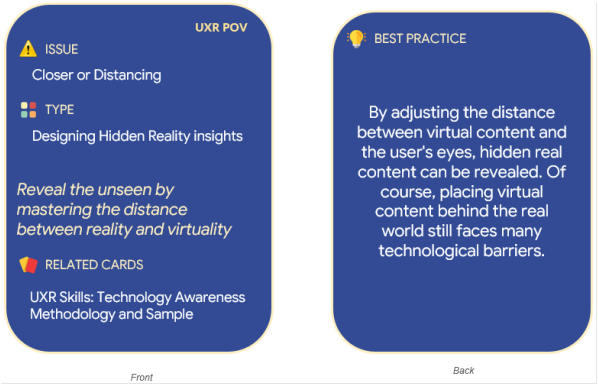

Fig. 5: Closer or distancing play cards in Hidden Reality awareness.

Fig. 6: Drag and Drop play cards in Hidden Reality awareness.

These play cards, whose format is inspired by the UX paper template [2], highlight the need to carefully manage the overlay of virtual content to avoid fully blocking the view of the physical world. This is critical for AR usage contexts where users still need to visually perceive their real surroundings. Techniques such as resizing, separating (additional setting might be required), transparency, and drag-and-drop features are now standard in the latest AR/VR devices, like Apple Vision Pro [20] and Meta Quest [21]. However, the ability to manipulate virtual content's proximity, specifically hiding it behind real content or bringing the real content closer, is not yet available in these devices. Nowadays, two play cards including diminishing Virtual Content and Drag and Drop can be operated directly through hand gestures, but changing transparency and separating virtual content windows still require special functions to assist. In addition, these play cards can be combined with each up. For example, "Diminishing Virtual Content" and "Drag and Drop" play cards can be integrated into one single solution. Transforming virtual content to scale it down and change its position simultaneously through gestures.

C. Modality Play Cards

This paper further explores the play cards of Modality awareness in augmented reality (AR), emphasising the integration of multi-sensory experiences to enrich user interaction (Fig. 7). Specifically, it addresses three key modalities: audio, smell, and haptic/tactile sensations.

Here is a list of play cards within Modality awareness:

- Audio virtual Modality (Fig. 8)
- Smell virtual Modality (Fig. 9)
- Haptic/Tactile virtual Modality (Fig. 10)

Fig. 7: Hidden Reality awareness play cards within UXR-AR.

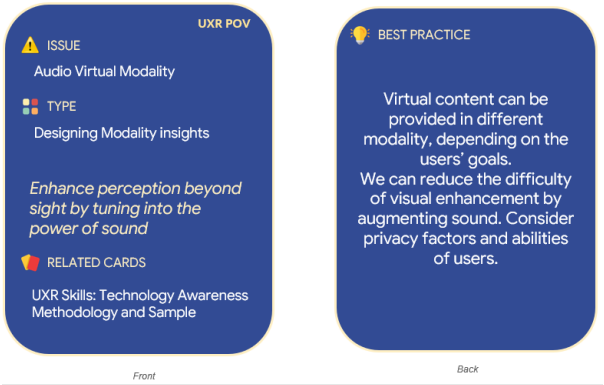

Fig. 8: Audio Virtual Modality play cards in Modality awareness.

Fig. 9: Smell Virtual Modality play cards in Modality awareness.

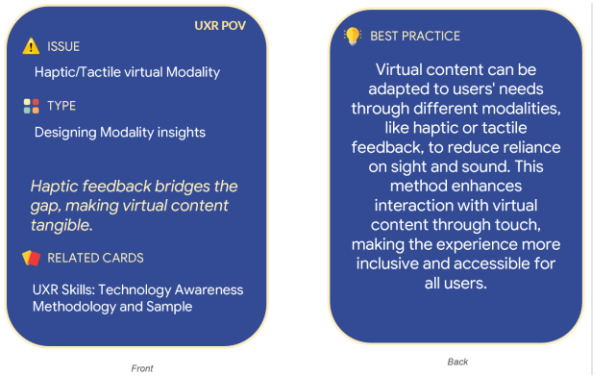

Fig. 10: Haptic/Tactile Virtual Modality play cards in Modality awareness.

Audio virtual Modality leverages sound to create immersive environments or provide navigational cues, enhancing the user's spatial awareness and engagement with the virtual content. For example, some studies have started to focus on audio augmented reality in different scenarios such as cars [15], museums [16], tourism [17] and others. Smell virtual Modality, though less common, offers unique opportunities for creating deeply immersive experiences by incorporating scent, thereby tapping into the user's olfactory senses to evoke memories or emotions. Erkoyuncu and Khan's article [18] outlined an olfactory-based AR system to help with the identification of maintenance issues using smell. Lastly, the haptic/tactile Modality in augmented reality (AR) uses physical sensations to bring virtual experiences to life. Haptic feedback involves vibrations or forces to simulate the sense of touch, allowing users to 'feel' virtual objects or actions, like the push of a button or the impact of an object. Tactile feedback, a subset of haptic sensations, specifically refers to textures and shapes, enabling users to perceive the smoothness of a surface or the edges of a virtual object. This distinction between haptic and tactile feedback enriches AR experiences by offering more nuanced interactions. Haptic feedback can convey actions and responses, while tactile feedback can simulate the physical characteristics of virtual environments and objects, making the virtual world feel more real and interactive. For example, Zhang et al.'s article [19] introduces innovative haptic devices enabled by curved origami. These devices allow users to actively experience a range of mechanical sensations, from softness to hardness and even the sensation of breaking, through user-initiated touch. This approach offers a more authentic and immersive virtual reality experience by closely mimicking real-world physical interactions. The technology's ability to simulate both positive and negative stiffness enhances the realism of virtual environments, presenting new possibilities for VR and AR applications across various sectors. However, Research in this area is still in the exploratory phase and has not yet led to the development of products.

Overall, these play cards offer valuable guidance for keeping the real-world view accessible while overlaying helpful virtual elements. Making the AR adaptable aligns with human-centred principles as well.

V. Conclusion

In conclusion, this study has embarked on a pioneering journey to bridge the gap in augmented reality (AR) user experience (UX) design by introducing the innovative concept of User Experience Research (UXR) play cards. Drawing inspiration from the Point of View (POV) UXR playbook, we have developed a series of play cards that encompass essential UX principles tailored specifically for Hidden Reality (see Fig. 11)) and Modality. These play cards serve as a dynamic toolkit, enabling UX practitioners to navigate the complexities of AR design with a structured and user-centric approach. Through the application of these play cards, our methodology not only addresses the 'Hidden Reality' and 'Modality' challenge but also enhances visibility and multi-sensation interaction within AR environments.

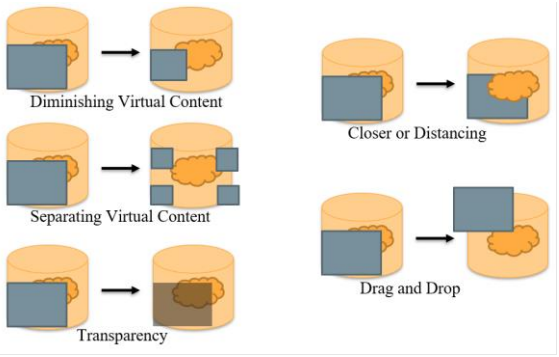

Fig. 11: The simplified diagram of Hidden Reality awareness in AR.

The strategic use of sensemaking throughout this process has illuminated the path forward, enabling our team to identify critical scenarios and insights that significantly contribute to the refinement of AR UX design. This study represents a significant step towards creating more meaningful and accessible AR applications. By leveraging the UXR play cards, we aim to inspire further innovation in the field (e.g. Modality, Accuracy, Instantaneous, Layer), encouraging practitioners to explore new horizons in AR UX design.

This study represents a significant step towards creating more meaningful and accessible AR applications. By leveraging the UXR play cards, we aim to inspire further innovation in the field: multi-sensational Modality, interaction between hand gesture and virtual content, transparency, bringing virtual screens closer or moving them further away, and the hidden relationship between real and virtual elements, encouraging practitioners to explore new horizons in AR UX design. Adding to this, this research introduces concrete examples of play cards in both data collection and insight generation levels within the UXR POV pyramid framework, suggesting the potential for future research to expand the play card system. Future investigations might also explore diverse play card formats across different levels of the pyramid and adapt the UXR POV pyramid structure to suit various scenarios, further enriching the AR design process and outcomes.

VI. LIMITATION AND FUTURE WORK

Limitations of this research include the focus on a specific set of UX principles tailored for Hidden Reality and Modality in AR. There should be more potential applicability of using UXR play cards to other aspects of technological design. Additionally, the effectiveness of the play cards in 'Hidden Reality' and 'Modality' remains to be fully validated through user testing and real-world application. Further user studies like workshop, focus group or interview could be conducted for evaluating the effectiveness of these play cards.

The further development of play cards could contribute to the refinement of the UXR POV theoretical framework. Additionally, researchers may draw inspiration from this endeavour to explore new methods for designing UX play cards. It could potentially bridge the gap between conceptual research and applied technology-related solutions.

ACKNOWLEDGMENT

We extend our heartfelt gratitude to all contributors and participants who made this study possible. Special thanks to our colleagues for their invaluable feedback and support throughout the research process. Additionally, we wish to express our sincere gratitude to Google for their support and resources that significantly contributed to this research. Our thanks extend to Renée Barsoum, an independent UX leader, whose insights and expertise were invaluable throughout the study.

REFERENCES

[1] B. Lee, M. Sedlmair, and Dieter Schmalstieg, 'Design Patterns for Situated Visualization in Augmented Reality,' *IEEE Transactions on Visualization and Computer Graphics*, pp. 1–12, Jan. 2023, doi: https://doi.org/10.1109/tvcg.2023.3327398.

[2] S. Giff, R. Barsoum, and H. Dogan, 'User Experience Research: Point of View Playbook', *in ACM CHI Conference on Human Factors in Computing Systems CHI 2024, Honolulu, Hawaii*, 2023, pp. 11–16.

[3] W. R. Sieck, G. Klein, D. A. Peluso, J. L. Smith, D. Harris-Thompson, and P. A. Gade, 'FOCUS: A model of sensemaking', *Fairborn, OH: Klein Associates*, 2007.

[4] S. Liang, 'Establishing design principles for augmented reality for older adults', *Doctoral dissertation*, 2018.

[5] S. Giff and H. Dogan, 'UX Research is Dead. Long live UX Research!', *in Electronic Workshops in Computing*, 2016.

[6] A. Tashakori et al., 'Capturing complex hand movements and object interactions using machine learning-powered stretchable smart textile gloves,' *Nature Machine Intelligence*, vol. 6, no. 1, pp. 106–118, Jan. 2024, doi: https://doi.org/10.1038/s42256-023-00780-9.

[7] S. Liang, 'Research Proposal on Reviewing Augmented Reality Applications for Supporting Ageing Population,' *Procedia Manufacturing*, vol. 3, pp. 219–226, 2015, doi: https://doi.org/10.1016/j.promfg.2015.07.132.

[8] Vida Davidavičienė, Jurgita Raudeliūnienė, and Rima Viršilaitė, 'User experience evaluation and creativity stimulation with augmented reality mobile applications,' *Creativity Studies*, no. 1, 2019, doi: https://doi.org/10.3846/cs.2019.3576.

[9] C. Papakostas, C. Troussas, A. Krouska, and C. Sgouropoulou, 'Measuring User Experience, Usability and Interactivity of a Personalized Mobile Augmented Reality Training System,' *Sensors*, vol. 21, no. 11, p. 3888, Jun. 2021, doi: https://doi.org/10.3390/s21113888.

[10] S. Liang, and C. Roast, 'Five Features for Modeling Augmented Reality', *HCI International 2014-Posters Extended Abstracts*, Springer International Publishing, 2014, pp. 607-612.

[11] R. T. Azuma, 'A Survey of Augmented Reality,' *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 4, pp. 355–385, 1997, doi: https://doi.org/10.1162/pres.1997.6.4.355.

[12] J. Rampolla, and G. Kipper. 'Augmented reality: An emerging technologies guide to AR'. *Elsevier*, 2012.

[13] D. D. Mascareñas *et al.*, 'Augmented reality for next generation infrastructure inspections,' *Structural Health Monitoring*, vol. 20, no. 4, pp. 1957–1979, Sep. 2020, doi: https://doi.org/10.1177/1475921720953846.

[14] J. C. Kim, T. H. Laine, and C. Åhlund, 'Multimodal Interaction Systems Based on Internet of Things and Augmented Reality: A Systematic Literature Review' *Applied Sciences*, vol. 11, no. 4, p. 1738, Feb. 2021, doi: https://doi.org/10.3390/app11041738.

[15] M. Kari, T. Grosse-Puppendahl, A. Jagaciak, D. Bethge, R. Schütte, and C. Holz, 'Soundsride: affordance-synchronized music mixing for in-car audio augmented reality'. In *The 34th Annual ACM Symposium on User Interface Software and Technology* , 2021 Oct 10, (pp. 118-133).

[16] F.Z. Kaghat, A. Azough, M. Fakhour, and M. Meknassi, 'A new audio augmented reality interaction and adaptation model for museum visits', *Computers & Electrical Engineering*, 84, p.106606, 2020.

[17] U. Chong, and S. Alimardanov, 'Audio augmented reality using unity for marine tourism', In *Intelligent Human Computer Interaction: 12th International Conference*, *IHCI 2020*, Daegu, South Korea, November 24–26, 2020, Proceedings, Part II 12 (pp. 303-311), Springer International Publishing, 2021.

[18] J. Erkoyuncu, and S. Khan, 'Olfactory-based augmented reality support for industrial maintenance'. *IEEE Access*, 8, pp.30306-30321, 2020.

[19] Z. Zhang *et al.*, 'Active mechanical haptics with high-fidelity perceptions for immersive virtual reality', *Nature Machine Intelligence*, vol. 5, no. 6, pp. 643–655, May 2023, doi: https://doi.org/10.1038/s42256-023-00671-z.

[20] 'Apple Vision Pro,' Apple. https://www.apple.com/apple-vision-pro (accessed Apr. 24, 2024).

[21] 'Meta Quest.' Meta. https://www.meta.com/gb/quest/ (accessed Apr. 24, 2024).