



Enabling embodied metaphors in new media arts: a multi-sensory augmented reality approach

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Abstract

Introduction. This study examines how multi-sensory augmented reality (MSAR), and embodied metaphor theory (EMT) can enhance immersion and comprehension in new media art. The installation, *The moon knows*, embodies four moon metaphors—romance, time, reunion, and self-discovery—to explore embodied interaction and audience perception.

Method. The system combined a tangible moon interface, Microsoft HoloLens 2, projection, and sensors linked to Unity3D and Arduino. Fifteen participants experienced four interactive chapters and provided feedback through questionnaires and semi-structured interviews.

Analysis. Quantitative data measured immersion, engagement, and understanding, while qualitative coding of interviews identified themes in multisensory interaction and metaphor perception.

Results. It proved possible to integrate MSAR with EMT in a new media artwork and to demonstrate that immersion and engagement were enhanced through embodied interaction. Results also revealed variations in how different metaphors were understood, with some concepts more intuitively grasped than others.

Conclusion. MSAR combined with EMT effectively enhances immersion and engagement in new media art. While abstract metaphors need clearer articulation, *The moon knows* shows how embodied multisensory design can foster emotional resonance and broaden interpretive possibilities. The potentials of MSAR being used in libraries and museums are discussed.

Introduction

New media art, emerging from the intersection of art and digital technology, encompasses a broad range of creative practices that leverage electronic media, virtual environments, and interactive installations (Takala, 2023). This evolution has transformed the way art is produced, experienced, and understood, pushing the boundaries of traditional art forms (Samuel J., 2025; Tribe et al., 2006). Enhancing audience engagement and effectively conveying conceptual messages are fundamental aspects of new media art, as they are essential for unlocking the medium's immersive and interactive potential. Engaging the audience not only makes the art experience more memorable and impactful but also facilitates a deeper understanding and appreciation of the underlying themes and ideas (Smith, 2016). By fostering active participation and emotional resonance, new media artists can create powerful, transformative experiences that communicate complex concepts in a more intuitive and relatable manner (Kwastek, 2016; Liu et al., 2024). This intersection of immersive media, sensory experience, and symbolic interpretation is also becoming increasingly relevant in broader public knowledge contexts, such as libraries, museums, and cultural heritage spaces, where interactive systems are used to promote understanding, reflection, and personal meaning-making. Experiences that allow users to interpret abstract ideas through embodied engagement can support new modes of learning and audience-centered cultural participation.

Embodied metaphor theory (Lakoff & Johnson, 2008) posits that abstract concepts and thought processes are deeply rooted in our physical and sensory experiences. According to this theory, our understanding and communication of abstract ideas are often framed through metaphors derived from our bodily interactions with the world (Gibbs et al., 2004). This connection between the physical and the conceptual provides a powerful tool for new media artists aiming to enhance audience engagement and effectively convey complex ideas. By aligning abstract ideas with physical experiences, intuitive and visceral connections with audiences can be created, and abstract concepts can be made more relatable and more accessible to grasp (Droumeva & Corness, 2008).

To effectively create the conditions required by embodied metaphors, integrating multi-sensory augmented reality (MSAR) into new media art can be a promising approach. MSAR enhances sensory engagement by incorporating visual, auditory, tactile, olfactory, and gustatory elements into the artistic experience (Bilbow, 2021a; Crofton et al., 2019). This multi-sensory input aligns seamlessly with embodied metaphor theory, which emphasizes the role of physical experiences in understanding abstract concepts (Gibbs et al., 2004). By engaging multiple senses simultaneously, MSAR can deepen the audience's interaction with the artwork, making abstract ideas more tangible and relatable (Bilbow, 2021b).

This study focuses on the multiple cultural metaphors of the moon, utilizing embodied metaphor theory and MSAR technologies to design and develop a new media artwork titled '*the moon knows*.' The project extracts four widely recognized cultural meanings of the moon: Romance, time, reunion, and self-discovery. Grounded in embodied metaphor theory, these abstract concepts are designed into an immersive, embodied experience for the audience, enabling them to perceive, understand, and reflect on these concepts in depth, through an interactive installation enhanced with multi-sensory augmentation. Following the implementation, we gathered 15 questionnaires and 12 interviews to assess system usability and user feedback.

Related work

New media art and embodied metaphor

New media art emerged in the late 20th century as artists began to explore the possibilities offered by new multimedia technologies (Gere, 2008; Tribe et al., 2006). The development of new media art has been driven by rapid advancements in technology and a growing interest in the dynamic relationship between art, technology, and society. As artists experiment with virtual reality,

augmented reality, and artificial intelligence, new media art continues to evolve, pushing the boundaries of how art can be created and experienced (Tribe et al., 2006). One of the defining characteristics of new media art is the importance of user engagement and immersion. Unlike traditional art forms, new media art frequently requires active participation, creating a more immersive experience (Kwastek, 2016). This engagement can take many forms, from interacting with digital interfaces to navigating virtual environments. The abstract concepts conveyed in new media art often rely on this interaction, as it allows for a deeper emotional and intellectual connection with the audience. Through the creation, artists can communicate complex ideas and emotions with the audience in ways that static, non-interactive media cannot, making the audience an integral part of the artistic experience.

Embodied metaphor theory, which posits that human cognition is deeply rooted in sensory and motor experiences, has great potential to be applied to new media art to enhance immersion and concept perception (Lakoff & Johnson, 2008). This theory emphasizes the central role of bodily experience in human cognitive architecture and offers a novel perspective on human thought and language (Gibbs et al., 2004). In practical applications, embodied metaphor theory has influenced fields such as human-computer interaction (Antle et al., 2011; Bakker et al., 2012; Kim & Maher, 2019) and education (Droumeva & Corness, 2008; Kiefer & Trumpp, 2012; Shapiro & Stolz, 2019). Research has shown that children using tangible metaphor systems to learn abstract musical concepts demonstrated superior accuracy in replicating sound sequences (Droumeva & Corness, 2008). Similarly, interactive environments using embodied schemas have enhanced the usability of novel interfaces, aiding comprehension of interactive modalities in augmented reality (Antle et al., 2009). Although embodied metaphor theory has been widely applied across various fields and proven effective in facilitating the understanding of abstract concepts and content, to the best of our knowledge, it has not yet been systematically applied in the domain of new media art. By applying the embodied metaphor theory, artworks can lower the barriers to art comprehension and more readily touch the inner worlds of viewers, stimulating emotional responses and encouraging audience participation through physical interactions and sensory engagement. While research integrating this theory into interactive art installations is still limited, its potential to guide creation and presentation in art and influence viewers' perceptions and resonance is significant, marking an important area for future exploration.

Multi-sensory augmented reality

In recent years, mixed reality (MR), including virtual reality (VR) and augmented reality (AR) technologies, has been widely adopted across education, culture, and the arts, with substantial evidence attesting to their effectiveness (Hu et al., 2021; Hu & Ng, 2025; Wang et al., 2024). In other fields, such as social virtual reality, immersive environments have also shown significant potential to foster emotional connection and shared presence (Zamanifard & Freeman, 2023). Public libraries have begun adopting MR as a tool for digital inclusion and creative exploration (Grodecki & Goulding, 2023), providing safe, participatory spaces for underrepresented groups to engage with immersive technologies. Multi-sensory augmented reality (MSAR) technology is an advanced version of AR that incorporates inputs from multiple senses, such as vision, hearing, and touch (Bilbow, 2021a; Lindeman & Noma, 2007). Traditional AR typically enhances the real-world environment by overlaying digital information within the user's field of vision. MSAR extends this concept by integrating feedback from various sensory modalities and heightens users' sense of reality and presence during interactions, creating a more immersive and authentic interactive experience and thereby increasing user engagement (Schraffenberger & Van Der Heide, 2016).

In recent years, MSAR has made significant advances in various fields, enhancing user experiences by blending digital and physical worlds. In education, Lindeman and colleagues highlighted the importance of combining VR/AR with tactile devices for multisensory learning in STEM education, advocating for the global promotion of this immersive model (Lindeman & Noma, 2007). In cultural

heritage education, MSAR is used in interactive installations at museums and historical sites to enhance visitors' immersion and engagement (Kwan et al., 2016). For example, Parker and others developed SensiMAR, a system that visually reconstructs ancient sites with sound effects and scent devices to recreate historical environments (Marto et al., 2021). At the 2015 Milan Expo, Cantoni and his team created a multisensory interactive exhibition for the 'Battle of Pavia,' allowing visitors, including those with low vision, to experience the event through various sensory channels such as tactile sensation and somatic sensation (Cantoni et al., 2018). In the arts field, MSAR in interactive installations expands the cognitive, emotional, and technical boundaries of art, creating profound and interactive experiences. Bilbow redefined MSAR as a medium for artistic creation through empirical research, allowing computer artists to produce more expressive works (Bilbow, 2021b). Following these ideas, contemporary art exhibitions started to integrate multisensory design. A salient example was the 'Tate Sensorium' exhibition at Tate Britain, which demonstrated the affordance of multisensory technology in making art emotionally compelling and stimulating, especially for abstract works (Vi et al., 2017).

Embodied metaphors theory emphasizes that understanding and thinking are achieved through bodily actions of experiencing and perceiving the world. MSAR technology can simulate real physical environments and interactions, making abstract concepts tangible and experiential. This enhances the expressiveness and depth of understanding metaphors, using different channels to provide rich sensory experiences that deepen audiences' immersion and engagement in new media art (Lakoff & Johnson, 2008). However, the application of MSAR combined with embodied metaphor in new media art remains quite limited, with the research on this approach being even more scarce. This study aims to examine the effectiveness of this approach in enhancing viewers' immersive experiences and communication of complex and abstract ideas through integrate MSAR into the design and implementation of a new media artwork with embodied metaphors, titled '*the moon knows*.'

The moon knows

The moon and its metaphors

Throughout history, the moon has been a prevalent symbol in literature and art, embodying a range of mysterious and romantic metaphors. Its rich emotional depth and multifaceted meanings make it a significant and profound symbol across global cultural traditions. Across different cultural contexts, the moon often serves as a powerful and versatile metaphor in literature and art, symbolizing a wide range of emotions and themes, such as time, change, reunion, and love. Inspired by the metaphors of the moon, this study, grounded in embodied metaphor theory, utilizes multi-sensory augmented reality (MSAR) technology to develop a new media artwork, '*the moon knows*.' This artwork establishes an immersive, mixed-reality environment that guides participants through various sensory dimensions to experience a profound narrative and artistic exploration about the metaphors of the moon. It aims to foster deep, personal engagement with the moon's metaphorical concepts through the following four distinct chapters.

Chapter 'knock'.

The moon has long symbolized affection across cultures, representing love and romance. Its gentle light evokes tender emotions, and its phases symbolize the departure and return of loved ones. In literature, it serves as both a companion in solitude and a bridge for distant lovers. In romantic depictions, flowers often accompany the moon, enhancing the sense of intimacy. The first chapter, 'knock,' immerses participants in a moonlit scene with blooming flowers and floating petals. It creates a poetic experience that evokes the warmth and beauty of the moon's metaphorical romance.

Chapter 'seek.'

The moon, with its unchanging glow amidst a world of constant change, has represented the passage of time. Its light, ever-present yet ever shifting, serves as a marker for life's transitions. Ancient poems about the moon serve as a vital and intuitive medium for the moon's time metaphor. Through these poems, people today can 'see' the moon of the past, linking to the stories and emotions carried by its light as it travels across the river of time. The chapter 'seek' explores this metaphor by revisiting classical Chinese moon poetry, inviting audiences to reconnect with ancient emotions and thoughts through interaction with the moon.

Chapter 'reunite.'

In East Asian cultures, the full moon is deeply associated with family reunions, harmony, and joy, most notably during the Mid-Autumn Festival which changes date every year but is always on an autumn night with a full moon. This celebration is a time for families to gather, share mooncakes, and admire the moon's radiant glow as a symbol of unity and togetherness. A tradition during the festival is the release of Kongming lanterns, which carry hopes and wishes for reunion and happiness. The chapter 'reunite' embodies these cultural themes, offering an immersive experience where peaceful music and glowing lanterns create an atmosphere of warmth, reflection, and the heartfelt connections that moonlit gatherings inspire.

Chapter 'breathe.'

In the stillness of the night, the moon serves as a source of solace, evoking profound self-reflection. Its soft, luminous glow encourages introspection and the pursuit of personal meaning, guiding individuals on a journey toward self-discovery. Similarly, a tranquil meadow symbolizes serenity, offering a refuge from the clamour of daily life, where one can reconnect with their inner self. The final chapter, titled 'breathe,' employs this imagery to cultivate a meditative experience beneath the moonlight, promoting reflection and inner tranquillity.

Structure and space design

To create an immersive interactive space and artistic experience, the interactive system features a tactile moon interface, a pair of AR glasses (Microsoft HoloLens2), a projector, and a computer as the control centre. For multi-layered displays in space, the AR glasses and spatial projection provide both personal and public artistic presentation. Figure 1 shows the system's overall composition and prototype design. The setup is placed in a relatively enclosed and quiet environment to ensure optimal display from the AR glasses and spatial projection, allowing participants to engage without distractions. The brightness of the space is dimmed to maintain a calm, noise-free environment. In this space, one wall serves as the main projection surface. In front of this wall, a 1.2-meter-high stand holds a 20 cm diameter tangible moon interface, with no obstacles around to impede movement. The stand is positioned slightly to the left of the projection wall, ensuring it does not block the projection while allowing easy interaction. In the process of experience, participants will stand near the tangible moon, wearing AR glasses, facing the projection wall.

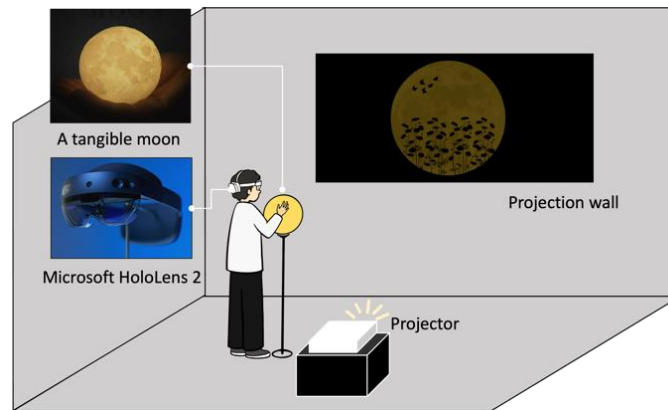


FIGURE 1. The interaction space of 'the moon knows.'

Interaction design

The four chapters of *'the moon knows'* are centered around the aforementioned four metaphors and the corresponding designs. In the process of experience, audiences can interact with the tangible moon interface and AR glasses through tangible manipulations, mid-air gestures, and eye movement to trigger feedback and immerse themselves in the mixed reality (MR) environment.

Once a participant puts on the holographic headset, the experience starts with the first chapter, 'knock,' as shown in Figure 2. Participants can lightly tap the tangible moon, causing it to light up gently. After the moon illuminates, petals start to fall in the AR space, circling around the tangible moon. Participants can hear petals blown by the wind. By reaching out their left hands, participants can attract petals to their fingertips. They can also extend their right hand with the palm facing up, and a flower will appear and bloom at their fingertips. As the flower blooms, clouds on the wall projection disperse, revealing shadows of flowers swaying in the moonlight.

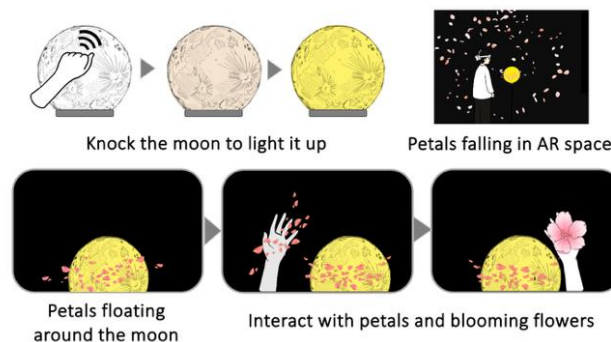


FIGURE 2. Interactions in the chapter 'knock.'

As shown in Figure 3, in chapter 2, 'seek,' participants can view four moon-related Chinese ancient poems floating around the tangible moon through the AR glasses. Each poem describes the moon's unique atmosphere and emotions in different contexts. As participants gently rotate the tangible moon, the poems rotate synchronously, allowing them to browse and select. By clicking each poem mid-air, a glowing particle flies out from the moon's surface, eventually revealing the full poem at the particle's endpoint in AR space. The projection wall then gradually displays a visual scene corresponding to the selected poem.

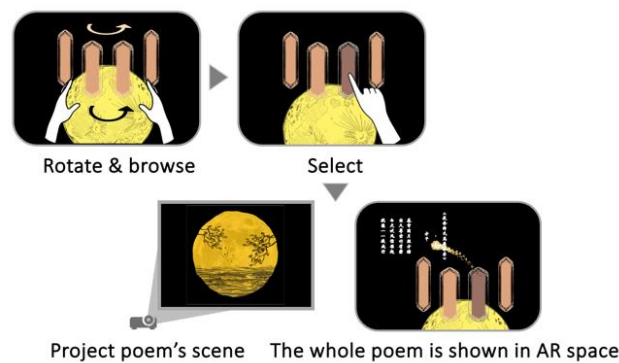


FIGURE 3. Interactions in the chapter 'seek.'

In chapter 3, 'reunite,' the space projection shows a traditional Chinese window through which participants can see fireworks bursting in the night sky. Participants hear celebration, laughter, clomp glasses, and fireworks. Participants are guided to rhythmically tap the tangible moon to trigger a cheerful melody played with Guqin, an ancient Chinese music instrument. Following this, participants will see several illuminated Kongming lanterns, which are traditional symbolizing prayers for good luck on the night of a full moon, slowly rising around the moon in interactive space from the AR perspective. Participants can reach out their hands to catch and gently manipulate these lanterns, which continue to float and ascend into the night sky once released, as shown in Figure 4.

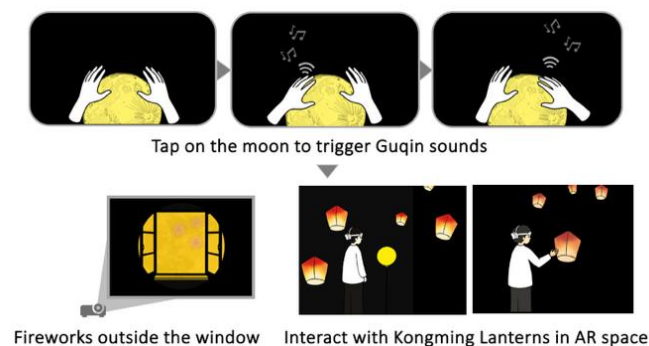


FIGURE 4. Interactions in the chapter 'reunite.'

As shown in Figure 5, in the final chapter, 'breathe', participants place their hands lightly on the sensor area next to the tangible moon, causing its light to pulse in sync with breathing. Participants can align their breathing with the moon's changing light to practice breathing meditation. At this point, space features the sound of ocean waves, with the rhythm matching the moon's brightness changes. After 5 seconds of breathing meditation, the moon's light stabilizes, and a field of glowing grass appears around the participant in the AR space. Participants can interact with the glowing grass by gazing at it for 3 seconds, causing the grass to release golden particles into the air.

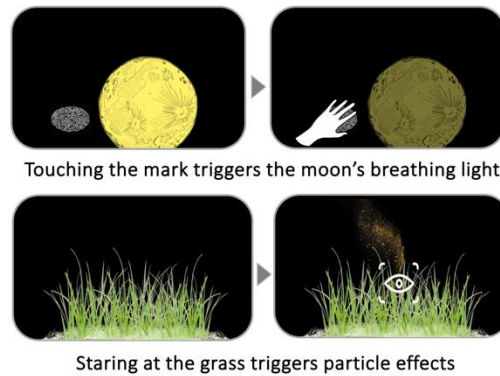


FIGURE 5. Interactions in the chapter 'seek.'

The moon knows

Figure 6 shows the technical framework of 'the moon knows.' The whole system is built on the Unity3D game engine. For the development of the tangible interaction module, an Arduino UNO R3 development board was selected and combined with various sensors, including a vibration sensor, an MPU6050 gyroscope, and a touch sensor. These sensors enable the system to accurately capture various haptic interactions between the user and the tangible moon model, such as tapping, rotating, and touching. For the AR interaction module, the system uses Microsoft HoloLens2 as the operating and display device. As shown in Figure 6, the HoloLens2 headset captures the user's hand gestures and eye movements, which, together with signals and data from haptic interactions, are fed into a Unity3D program. The final rendering output of the system focuses mainly on visual and auditory dimensions. The visual outputs are realized through LED bulbs embedded in the tangible moon, wall projections, and the AR glasses built in Microsoft HoloLens2.

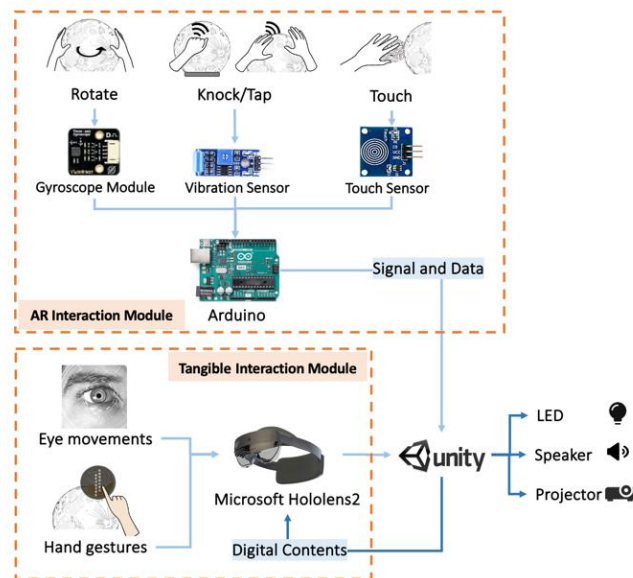


FIGURE 6. The technical framework of 'the moon knows.'

The tangible moon model (Figure7-a) was 3D printed with Autodesk Fusion 360. It's hollow with 1 mm-thick walls for strength and material efficiency. The surface mimics the moon's terrain, and the base opening, which is 75mm in diameter, accommodates an Arduino, LEDs, and sensors for interactivity. A custom aluminum alloy bearing (70mm inner, 120mm outer diameter) with rubber pads ensures smooth rotation.

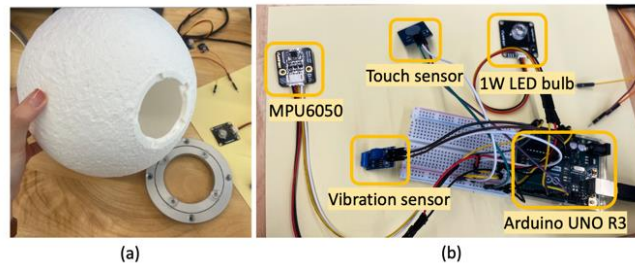


FIGURE 7. a: 3D-printed moon model and its bearing. b: Arduino Uno R3 and different input/output modules connected to it.

Tangible interaction implementation

To implement the tangible interaction module, an Arduino Uno R3 microcontroller serves as the central unit, integrating various components to develop the interactive logic. A vibration sensor detects taps, an MPU6050 gyroscope tracks moon rotation, and a touch sensor detects touch inputs. Figure 7-b illustrates the sensor connections to the Arduino board. Using its integrated development environment (IDE), we wrote a C++ program to manage signal transmission between modules and uploaded it to the Arduino board. Most user inputs on the tangible moon interface should trigger responses to be shown in the AR glasses and/or the spatial projection. To enable this, communication between the Arduino board and Unity3D is also established using the Ardity library and controlled scripts in Unity3D.

In the ‘*knock*’ chapter, we utilize a DFRobot vibration sensor to detect taps on the moon and send signals to the Arduino board. Subsequently, Pulse-Width Modulation (PWM) (Sun, 2012) is employed to regulate the brightness of an internal 1W LED from dim to bright. This produces a seamless lighting change effect when the moon is tapped. The same sensor is utilized in the ‘*reunite*’ chapter, where taps trigger unique sound effects in Unity3D. Signals are sent from the Arduino board through a serial port to Unity3D, facilitated by the Ardity library and custom scripts. Unity3D then randomly selects and plays sound clips of the Guqin available in Pixabay, a free platform offering copyright-free multimedia resources, generating an improvisational musical experience. In the ‘*seek*’ chapter, an MPU6050 gyroscope is embedded in the moon model to track its orientation. When the moon is rotated, its orientation data is sent to Unity3D using Ardity and custom scripts. The Unity3D scripts then control the display of poetry scrolls in the AR space, causing them to rotate in the same direction and angle. This synchronizes the rotation of the AR digital content with the participants’ rotation of the moon model. In the ‘*Breath*’ chapter, when the specific area around the moon model is touched, the TTP223 sensor detects the input and sends a signal to the Arduino board. The custom script on the board then processes this signal and starts gradually adjusting the PWM duty cycle—the percentage of time the signal is in the ‘on’ state during each cycle. By smoothly increasing and decreasing the duty cycle, the script controls the brightness of the mood light, creating a rhythmic ‘*breathing*’ effect as the light intensity rises and falls.

Augmented reality (AR) interaction implementation

In the AR interaction module, we use the Microsoft HoloLens 2 device as the interface, which supports the Microsoft mixed reality toolkit (MRTK), an open-source toolkit that offers various interaction patterns and UI elements. By leveraging MRTK along with custom scripts in Unity3D, we can create interactions based on gesture recognition and eye tracking, allowing users to interact with AR content naturally without the need for additional input devices. The interactions in the first three chapters focus on hand tracking and gesture interaction. This involves developing hand joint recognition tracking and gesture effects on HoloLens 2. Using Unity3D, we leverage the depth camera and spatial awareness capabilities of the HoloLens 2 to achieve hand joint

recognition and tracking. The device captures and recognizes the positions and movements of 22 joints in the user's hand, while Unity, through MRTK, interfaces with HoloLens 2 to access and recognize the hand data.

In the 'knock' chapter, gesture interaction is implemented through scripts and MRTK that recognize the palm-up gesture. Once the gesture is detected, a 3D flower model is dynamically placed on the user's palm. Similarly, the petal particle system floating around the user's fingertip is achieved by tracking the finger joints and adding appropriate materials. In the 'reunite' chapter, HoloLens's hand gesture recognition capabilities combined with MRTK scripts for object-grabbing logic, enable participants to manipulate Kongming lanterns using grabbing gestures. In the 'seek' chapter, the Vuforia Engine is used to recognize the position of a tangible moon model in the real world and attach the virtual objects and visual effects in AR perspectives based on it during interactions. Poems in this chapter are integrated with individual buttons in the Unity3D scene, allowing interaction through mid-air-click gestures on those buttons. When the gesture is recognized, the customized script triggers the following displays of AR and projected contents. In the 'breathe' chapter, participants can trigger particle effects in the grass by gazing at it. Eye-tracking interactions in Unity3D for HoloLens 2 are based on advanced eye-tracking technology, utilizing infrared illumination and eye-tracking cameras to capture eye reflection patterns and analyze the participant's line of sight and focal point. The participant's gaze information is analysed through custom scripts and MRTK, and a beam of golden particles is triggered to flow out from the grass when participants are detected staring at it for more than 3 seconds.

User feedback

Participants and process

To explore the user experience and the effectiveness of metaphorical concepts conveyed in 'the moon knows,' we conducted a user experience study with 15 participants, 12 of whom also took part in exit interviews. Participants were recruited from the university community using a convenience sampling method. By analyzing the participants' feedback through questionnaires (N=15) and interviews (N=12), we aimed to gain insights into the performance and areas for improvement in using embodied metaphor theory and MSAR technologies to enhance the delivery of metaphorical and abstract contents in new media artwork.



FIGURE 8. Participants were experiencing 'the moon knows'

The user study began with a brief introduction to the participants, providing an overview of 'the moon knows' and instructions on interaction. After finishing the eye calibration in HoloLens 2, participants were given a practice session to familiarize themselves with HoloLens 2 and the tangible interface. During this practice period, they could freely explore the functionalities and get comfortable with the controls. Following the practice session, participants began to experience the four chapters of 'the moon knows' sequentially (Figure 8). Participants were informed that they

could pause or withdraw from the experience at any time, and short breaks were offered between chapters to minimize potential discomfort. Upon completing the entire interactive process, participants were asked to complete a questionnaire aimed at assessing their levels of immersion, engagement, and comprehension of the four metaphors. Each construct was measured using a set of four 5-point Likert-scale items (1 = strongly disagree, 5 = strongly agree), adapted from prior validated scales in immersive media experience research (Shin, 2019) and supplemented with custom items designed to assess the comprehension of the four metaphors. Subsequently, most participants took part in a semi-structured interview to provide in-depth feedback on their experiences. Oral informed consent was obtained from all participants prior to their involvement in the experience.

Results

The questionnaire assessed immersion, engagement, and understanding of metaphors in *'the moon knows,'* with four questions dedicated to each aspect. Upon analysis of 15 participants, 93% (14 participants) of participants reported feeling fully immersed in the experience, with 87% (13 participants) experiencing an altered sense of time. Furthermore, over 60% (10 participants) found the gesture and eye-tracking interactions to be seamless, while 93% (14 participants) expressed a strong sense of connection to the virtual moon. These results suggest the successful creation of a highly immersive and engaging interactive environment. Furthermore, while 60% (9 participants) of participants felt actively involved in exploration, all participants found the interaction engaging. There was a unanimous desire to spend more time exploring the installation, and 80% (12 participants) felt their actions influenced the experience, showcasing high levels of engagement and a sense of control. However, participants' grasp of the moon's metaphors varied across chapters. While all participants resonated with the metaphors of romance and reunion in the first and third chapters, only 53% (8 participants) grasped the time metaphor in the second chapter, and just 20% (3 participants) connected with the self-awareness concept in the fourth chapter. This may be because, for most Chinese individuals, the moon is deeply associated with romance and reunion, largely due to its prominent role in traditional festivals and literature that emphasize familial bonds and love. In contrast, fewer people perceive it as a symbol of time and self-awareness, as these interpretations are less emphasized in cultural narratives and collective consciousness. Additionally, these two concepts are more abstract compared to the others and can elicit a wide range of interpretations depending on the individual. The interaction design and the extraction of concrete elements in these two chapters may not be sufficiently intuitive in conveying these concepts, which increases the difficulty for participants to fully comprehend them. These findings highlight a need for improved design articulation of those extremely abstract and in-depth concepts to enhance clarity and participant understanding.

The semi-structured interviews further explored participants' interactive experiences across the four chapters, as well as their understanding, associations, and reflections on the content. Additionally, we gathered their suggestions for improving the work. We conducted inductive thematic analysis (Braun & Clarke, 2006). Two researchers independently coded the transcripts and refined themes through discussion. Upon organizing and analyzing the results of the semi-structured interviews, feedback was categorized into two subdivisions:

Feedback and interaction of multi-sensory design.

Almost all participants reported that this new media artwork, which engaged multiple senses, such as sight, hearing, and touch, provided a strong sense of immersion and presence. Integrating AR and tangible interaction allowed them to freely transit between the virtual and physical worlds, offering a novel and fantastical perception. The system's ability to respond to their actions in real time ensured that every interaction received clear and immediate feedback, fostering a dialogue between the participants and the artwork and enhancing their sense of control and engagement. This was evidenced by Participant #7 (P7)'s sharing: *'I really enjoyed this immersive experience. The*

installation offered not only visual pleasure but also an encompassing feeling of being present in space. I felt completely immersed, as if I were truly conversing with the moon.' Participants also showed significant interest in the interactive physical moon, as remarked by P2: 'Having a tangible object to interact with within a virtual environment is fascinating; it makes the whole experience more real and engaging.' These responses reflect the participants' high level of acceptance and appreciation for this multisensory interactive form of new media art. They also highlight the potential and value of this design approach in areas such as enhancing audience engagement and providing immersive storytelling experiences. Such feedback highlights the broader potential of MSAR systems beyond artistic installations. In libraries, museums, and digital humanities contexts, MSAR can enable embodied engagement, deepen interpretive experiences, and foster personal connections with cultural artifacts. By bridging physical and digital modes of interaction, this approach may support new forms of storytelling, scholarship, and learning in public knowledge environments.

It is worth noting that some participants suggested that the forms of interaction with the moon and the feedback mechanisms could be made more diverse. For instance, incorporating changes in surface temperature as an interactive feedback method could introduce the sensation of the moon's temperature as an additional dimension, enhancing the richness and depth of the experience. The interaction with the moon could take on more varied forms, such as gently stroking its surface or embracing it with both hands. These softer, more emotionally resonant gestures could further expand the expressive potential of the work, allowing for a deeper emotional connection and richer interaction.

Perception of the metaphors of the moon.

The interview further explored participants' understanding of the conceptual metaphors of the moon in *'the moon knows.'* Most participants gave positive feedback on the metaphorical conveyance. Many participants expressed that their interaction with *'the moon knows'* evoked emotional reflections on the moon and sparked curiosity about the multiple symbolic meanings behind it. P1 shared: *'Before this experience, I rarely thought deeply about the moon and its emotional ambiance. This experience deepened my understanding of its imagery.'*

When we explained the specific concepts represented in each of the four chapters during the interviews, most participants indicated that these concepts closely aligned with what they had felt through their interactive experiences, particularly in the content of the first and third chapters. However, as the results of the questionnaire show, some participants felt that certain concepts, such as *'time'* and *'self'* in the *'seek'* and *'breathe'* chapters, were somewhat obscure. Those participants felt that the interactive content of these chapters remained somewhat abstract and did not explicitly convey the corresponding concepts. Instead, it created an atmosphere that led to a wide range of different interpretations. Therefore, when expressing these highly abstract and multi-faceted concepts, adding more concrete elements, like changes in moon phases or bronze mirrors, could help with the participants' perception and understanding of these concepts.

Interestingly, *'the moon knows'* also sparked personal interpretations and imaginations about the moon among many participants based on their personal experiences and memories. For example, P8 felt that the four chapters represented a continuous story depicting four different stages of a romantic relationship. Reflecting on the contrasting atmospheres of the lively third chapter and the quiet, solitary fourth chapter, P10 was reminded of a lost loved one, evoking a deep sense of longing and remembrance. This also prompted us to reflect on the diverse interpretability of art, recognizing that different individuals may approach concepts from varying perspectives.

CONCLUSION

In this paper, we design and develop *'the moon knows,'* a new media art installation leveraging MSAR and embodied metaphor theory to convey the moon's metaphors of romance, time, reunion, and

self-discovery. We gathered and analysed user feedback from 15 questionnaires and 12 interviews. The results suggest that integrating multi-sensory augmented reality into new media artwork based on embodied metaphor can enhance users' immersion, engagement, and understanding of abstract concepts. This work contributes a prototype and a conceptual approach that may inform future practices in interactive art and embodied media design. Beyond artistic contexts, this research also carries implications for public knowledge institutions such as libraries and museums. As these spaces navigate evolving audience expectations and resource constraints, MSAR-based embodied experiences offer promising pathways for inclusive engagement, cultural learning, and participatory storytelling. For instance, similar systems could be adapted for thematic exhibitions, sensory-rich educational programs, or accessible cultural interfaces. Although immersive installations require initial investment, their potential to foster emotional resonance and deepen conceptual understanding can support their adoption in cultural programming. By demonstrating how abstract ideas can be made experientially tangible, our work highlights a direction for designing meaningful and memorable audience experiences in broader societal contexts.

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References

- Antle, A. N., Corness, G., & Droumeva, M. (2009). What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments. *Interacting with Computers*, 21(1-2), 66-75. <https://doi.org/10.1016/j.intcom.2008.10.005>
- Antle, A. N., Marshall, P., & Van Den Hoven, E. (2011). Workshop on embodied interaction: Theory and practice in HCI. *CHI '11 Extended Abstracts on Human Factors in Computing Systems*, 5-8. <https://doi.org/10.1145/1979742.1979592>
- Bakker, S., Antle, A. N., & van den Hoven, E. (2012). Embodied metaphors in tangible interaction design. *Personal and Ubiquitous Computing*, 16(4), 433-449. <https://doi.org/10.1007/s00779-011-0410-4>
- Bilbow, S. (2021a). Developing Multisensory Augmented Reality As A Medium For Computational Artists. *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*, 1-7. <https://doi.org/10.1145/3430524.3443690>
- Bilbow, S. (2021b). Developing Multisensory Augmented Reality As A Medium For Computational Artists. *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*, 1-7. <https://doi.org/10.1145/3430524.3443690>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>

- Cantoni, V., Dondi, P., Lombardi, L., Nugrahaningsih, N., Porta, M., & Setti, A. (2018). A Multi-Sensory Approach to Cultural Heritage: The Battle of Pavia Exhibition. *IOP Conference Series: Materials Science and Engineering*, 364(1), 012039. <https://doi.org/10.1088/1757-899X/364/1/012039>
- Crofton, E. C., Botinestean, C., Fenelon, M., & Gallagher, E. (2019). Potential applications for virtual and augmented reality technologies in sensory science. *Innovative Food Science & Emerging Technologies*, 56, 102178. <https://doi.org/10.1016/j.ifset.2019.102178>
- Droumeva, M., & Corness, G. (2008). Playing with the sound maker: Do embodied metaphors help children learn? *Proceedings of the 7th International Conference on Interaction Design and Children*, 178–185. <https://doi.org/10.1145/1463689.1463754>
- Gere, C. (2008). New media art and the gallery in the digital age. *New Media in the White Cube and beyond: Curatorial Models for Digital Art*, 13–25.
- Gibbs, R. W., Costa Lima, P. L., & Francozo, E. (2004). Metaphor is grounded in embodied experience. *Journal of Pragmatics*, 36(7), 1189–1210. <https://doi.org/10.1016/j.pragma.2003.10.009>
- Grodecki, K., & Goulding, A. (2023). Digital Experiences in Physical Spaces: Virtual Reality and Public Libraries in Aotearoa New Zealand. In I. Sserwanga, A. Goulding, H. Moulaison-Sandy, J. T. Du, A. L. Soares, V. Hessami, & R. D. Frank (Eds.), *Information for a Better World: Normality, Virtuality, Physicality, Inclusivity* (pp. 157–170). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-28032-0_13
- Hu, X., & Ng, J. T.-D. (2025). Low tech-barrier virtual reality content creation for cultural heritage education: Learning outcomes and pedagogy. *Technology, Pedagogy and Education*, 1–28. <https://doi.org/10.1080/1475939X.2025.2503768>
- Hu, X., Ng, J. T.-D., & Liu, R. (2021). Development and Evaluation of a Digital Museum of a National Intangible Cultural Heritage from China. In K. Toeppe, H. Yan, & S. K. W. Chu (Eds.), *Diversity, Divergence, Dialogue* (Vol. 12646, pp. 493–501). Springer International Publishing. https://doi.org/10.1007/978-3-030-71305-8_42
- Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education*, 1(1), 15–20. <https://doi.org/10.1016/j.tine.2012.07.002>
- Kim, J., & Maher, M. L. (2019). Metaphors, Signifiers, Affordances, and Modalities for Designing Mobile and Embodied Interactive Systems. *Proceedings of the 31st Australian Conference on Human-Computer-Interaction*, 542–545. <https://doi.org/10.1145/3369457.3369527>
- Kwan, J., Chu, J. H., Harley, D., McBride, M., & Mazalek, A. (2016). Grasping Cultural Context through Multisensory Interactions. *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, 482–487. <https://doi.org/10.1145/2839462.2856537>
- Kwastek, K. (2016). Immersed in Reflection? The Aesthetic Experience of Interactive Media Art. In *Immersion in the Visual Arts and Media* (pp. 66–85). Brill. https://doi.org/10.1163/9789004308237_005
- Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago press. <https://books.google.com/books?hl=zh-CN&lr=&id=r6nOYYtxzUoC&oi=fnd&pg=PR7&dq=Metaphors+We+Live+By&ots=Lpqabq4A4X&sig=x33mQck9umXLHhY-y4obzCDhr-I>

- Lindeman, R. W., & Noma, H. (2007). A classification scheme for multi-sensory augmented reality. *Proceedings of the 2007 ACM Symposium on Virtual Reality Software and Technology*, 175–178. <https://doi.org/10.1145/1315184.1315216>
- Liu, Y., Luo, Q., Zhou, Z., & Tian, Q. (2024). Empathy in Motion: A Case Study of “Dance of Youth” in Visual Art. *Advances in Education, Humanities and Social Science Research*, 12(1), 305. <https://doi.org/10.56028/aehtsr.12.1.305.2024>
- Marto, A., Melo, M., Gonçalves, A., & Bessa, M. (2021). Development and Evaluation of an Outdoor Multisensory AR System for Cultural Heritage. *IEEE Access*, 9, 16419–16434. <https://doi.org/10.1109/ACCESS.2021.3050974>
- Samuel J., K. (2025). The Intersection of Technology and Arts: New Mediums for Expression. *RESEARCH INVENTION JOURNAL OF RESEARCH IN EDUCATION*, 5(1), 45–52. <https://doi.org/10.59298/RIJRE/2025/514552>
- Schraffenberger, H., & Van Der Heide, E. (2016). Multimodal augmented reality: The norm rather than the exception. *Proceedings of the 2016 Workshop on Multimodal Virtual and Augmented Reality*, 1–6. <https://doi.org/10.1145/3001959.3001960>
- Shapiro, L., & Stolz, S. A. (2019). Embodied cognition and its significance for education. *Theory and Research in Education*, 17(1), 19–39. <https://doi.org/10.1177/1477878518822149>
- Shin, D. (2019). How does immersion work in augmented reality games? A user-centric view of immersion and engagement. *Information, Communication & Society*, 22(9), 1212–1229. <https://doi.org/10.1080/1369118X.2017.1411519>
- Smith, S. (2016). Ask the Audience. *Electronic Visualisation and the Arts*. <https://doi.org/10.14236/ewic/EVA2016.50>
- Sun, J. (2012). Pulse-Width Modulation. In F. Vasca & L. Iannelli (Eds.), *Dynamics and Control of Switched Electronic Systems: Advanced Perspectives for Modeling, Simulation and Control of Power Converters* (pp. 25–61). Springer. https://doi.org/10.1007/978-1-4471-2885-4_2
- Takala, G. B. (2023). The Interactive Creativity of the Digital Era: Exploring How Media Art Redefines the Relationship Between Audience and Artwork. *Studies in Art and Architecture*, 2(3), 28–44.
- Tribe, M., Jana, R., & Grosenick, U. (2006). *New media art*. Taschen Cologne. http://llrc.mcast.edu.mt/digitalversion/Table_of_Contents_128114.pdf
- Vi, C. T., Ablart, D., Gatti, E., Velasco, C., & Obrist, M. (2017). Not just seeing, but also feeling art: Mid-air haptic experiences integrated in a multisensory art exhibition. *International Journal of Human-Computer Studies*, 108, 1–14. <https://doi.org/10.1016/j.ijhcs.2017.06.004>
- Wang, F., Zhang, Z., Li, L., & Long, S. (2024). Virtual Reality and Augmented Reality in Artistic Expression: A Comprehensive Study of Innovative Technologies. *International Journal of Advanced Computer Science and Applications*, 15(3). <https://doi.org/10.14569/IJACSA.2024.0150365>
- Zamanifard, S., & Freeman, G. (2023). A Surprise Birthday Party in VR: Leveraging Social Virtual Reality to Maintain Existing Close Ties over Distance. In I. Sserwanga, A. Goulding, H. Moulaison-Sandy, J. T. Du, A. L. Soares, V. Hessami, & R. D. Frank (Eds.), *Information for a Better World: Normality, Virtuality, Physicality, Inclusivity* (pp. 268–285). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-28032-0_23

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