Environment Extension: A Passive Interactivity Approach to Immersive AR/MR

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ABSTRACT

Nascent augmented reality/mixed reality (AR/MR) experiences are emerging across the Department of Defense (DOD) training and operational ecosystems. Immersive AR/MR experiences can garner cognition efficiencies in simulation or in battlespace, but designing for immersion and increased presence has proven elusive across this bourgeoning arena. The obscurity is due in part to a lexicon built for fully synthetic virtual reality (VR) experiences. As an example, the term *presence* in VR is often associated with a feeling of "being there" in a remote synthetic location; however, in AR/MR, "there" is often right where you are, so defining *presence* becomes more nuanced. Beyond problematic terminology, AR/MR experiences have expanded the boundaries of how users engage and spatially interact with synthetic content and conversely, how synthetic content interacts with the intrinsic physical environment. This paper explores how optimizing for passive spatial interactivity, in particular environmental interactions at the seam of the physical and synthetic boundary unique to AR/MR, will maximize a holistic sense of *presence* through a proposed theory of *environment extension*, ultimately leading to enhanced immersive experiences. Borrowing from the concept of "self-extension" (Belk, 1988), the author contends that *environment extension* can be leveraged to passively establish environmental *presence* by influencing the user's physical surroundings and manipulating the individual's subconscious feeling of extended self-identity. Different types of spatial interactivity and their utility in enhancing *presence* in AR/MR environments are discussed, followed by several recommendations on passive environmental interactivity strategies. By exploiting immersive AR/MR experiences by way of passive environmental interactions, the DOD can expect better learning outcomes through an improved affective training medium, as well as increased productivity in the office or in battle by offloading cognition.

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INTRODUCTION

When talking on a phone, one can feel immersed in a conversation. When reading a book, one can feel immersed in a story. When watching a movie or playing a video game, one can escape to a thrilling narrative. Two-dimensional media platforms have come a long way, but those experiences and human-to-human exchanges still feel distant and artificial. Immersive augmented and mixed reality (AR/MR) experiences have the capability to submerge users in an alternate reality or put working professionals on opposite ends of the country in the same room and make them feel like they are right next to each other. Nascent AR/MR experiences are emerging across the Department of Defense (DOD) training and operational ecosystems. Enhanced immersion during AR/MR experiences can garner cognition efficiencies in simulation or in battlespace but designing for immersion and increased presence has proven elusive across this bourgeoning arena.

The obscurity is due in part to a lexicon built for fully synthetic virtual reality (VR) experiences. *Presence* in virtual environments is often thought of in a binary way. You are either present in a virtual world or present in the physical world. In AR/MR, *presence* tends to converge at the intersection of synthetic and virtual environments, where a new hybrid reality and sense of presence is born. Thinking about *presence* and immersion in terms of location may be conceptually limiting; rather, investigations into *presence* within AR/MR should be viewed through a narrative prism and composed of a confluence of active and passive spatial interactions within the hybrid environment. However, spatial interactivity's most potent attribute has been underexplored to date. Today's AR/MR experiences typically use spatial computing to simply drop synthetic content in space as if the object were sitting on a table or floating in front of you. This basic methodology has utility but does not fully exercise spatial computing's potential. Harnessing the often-overlooked human sense of space — proprioception — and coherently integrating spatial synthetic AR/MR content in a way that enables the user to intuitively navigate the experience is key. Many strive for the user to forget the computer is there; the real goal is to enable the user to accept the computer is there.

Given DOD military construction (MILCON) dollar limitations of building new buildings on bases, office space requirements have become severely strained. By enabling teleworkers and distributed team members an effective, more *present* way to collaborate in an AR/MR office environment, the DOD can minimize desk and conference room requirements. Leaders and Commanders would be able to expand their reach to geographically separated units to check in on their personnel or simply have more impactful virtual engagements. This space- and time-saving strategy can also be extended directly to acquisition source selection teams as well, where temporary isolation of entire teams is required to preserve the competition-sensitive nature of contractor proposal evaluations. When companies bid on defense contracts, it's imperative that the DOD ensures a fair, unbiased government evaluation. AR and MR's ability to setup synthetic source selection rooms and augment collaboration offsite uniquely positions AR/MR to develop more engaging social *presence* interactions when using distributed talent management strategies and supporting the acquisition community in meeting statutory federal requirements.

This paper explores how optimizing for passive spatial interactivity, in particular environmental interactions at the seam of the physical and synthetic boundary unique to AR/MR, will maximize a holistic sense of *presence* through a proposed theory of *environment extension*, ultimately leading to enhanced immersive experiences. Borrowing from the concept of "self-extension" (Belk, 1988), the author contends that *environment extension* can be leveraged to passively establish environmental *presence* by influencing the user's physical surroundings and exploiting the individual's subconscious feeling of extended self-identity. Different types of spatial interactivity and their utility in enhancing *presence* in AR/MR environments are discussed, followed by several recommendations on passive environmental interactivity strategies.

TYPES OF SPATIAL INTERACTIVITY

Interactivity, or interaction, has generally been defined as the user's ability to modify the virtual environment (Ryan, 1994). Others have described interactivity as "the ability for a user to stop, start, replay, and manipulate visuals at his or her own pace" (Thompson et al., 2018). More broadly and encompassing of AR/MR's nuances, the human-computer interaction community has often referred to interactivity as simply communication between users and systems. Interactivity enables the user to communicate (interact) with the environment, objects, and social agents just as a user would expect in the real world. In a VR environment, interactivity is purely synthetic. The user interacts with synthetic objects and agents inside a fully simulated environment. In contrast, interactivity in AR and MR environments can occur between the user and both the synthetic and physical worlds. AR/MR opens new possibilities to merging the synthetic and physical worlds through physical augmentation of the synthetic, and synthetic augmentation of the physical. This bi-directional influence is unique to sophisticated AR/MR environments and reveals a new dimension of interactivity.

There are three basic relationships of spatial interactivity: (1) interactions with objects, (2) interactions with agents, and (3) interactions with the environment. In AR/MR, these interactions can occur at the intersection between physical and synthetic spatial environments. Unique to AR/MR experiences, these spatial interactivity relationships can be spurred by inputs from the user and the surrounding physical environment. Within each spatial interactivity relationship there are multiple sensory modalities that can be leveraged to enrich each relationship, to include sight, auditory, haptics, olfactory, speech, respiratory, muscular, brain control, gestures, eye tracking, and other physiological stimuli.

Interactions between users and objects are the most common and basic form of spatial interactivity. Interactions between users and synthetic objects are well understood from the advent of numerous VR platforms available today. Unlike fully synthetic VR environments, AR/MR environments enable these interactions to occur between the user and physical objects in addition to synthetic object interactivity. Given the user's ability to see the physical environment through a mobile device or AR/MR head-mounted display (HMD), physical object interactions can occur naturally or in a mediated way. When physical objects are used as a medium for interfacing with computers, the human-computer communication world refers to these interactions as a "3D user interface" or "tangible user interface" (Billinghurst et al., 2015). Traditional 3D user interfaces are manufactured control devices deliberately designed to manipulate synthetic content such as a mouse, game controller or wand. Tangible user interfaces allow everyday physical objects to serve as input and output devices to influence synthetic content through computer mediation. This mediation can take the form of an anchor point for synthetic 3D content to manifest from, to direct spatial manipulation between physical object and synthetic content. Specific to the latter, when mediation goes beyond a simple one-way synthetic representation and extends to a bi-directional synthetic interface capable of receiving inputs to control synthetic content, this object has been called a "virtual-physical tool" (e.g., synthetic menu or panel displayed over one's wrist) (Schmalstieg & Höllerer, 2016). When tangible user interfaces are utilized in AR, this activity is regarded as "tangible AR" (Schmalstieg & Höllerer, 2016).

Spatial interactivity encompasses interactions between users and agents as well. Agents may take the form of other users or synthetic actors. For a user, these social interactions contribute to an elevated sense of *presence* by mimicking what you would expect in the real world. This idea of *social presence* describes the effect when other social agents engage with and respond to the user, the user's existence of self is realized (Heeter, 1992). When the user feels acknowledged, they feel increased *presence* and are more apt to accept the mediated experience as actually happening. According to McMahan (2003), even when integrating synthetic social actors, to include virtual guides and pets, users respond much in the same way they respond to real actors, leading to an amplified sense of *presence*. AR/MR experiences enable users to undergo *social presence* from physical actors in addition to synthetic actors, clouding the barrier between real and mediated experiences. When utilizing real actors as part of the immersive experience, *social presence* is heightened further given the idyllic realism afforded by interactivity with real people. When the other agent is an intended user (real or virtual human) inside the AR/MR, user-to-user interactions in games or collaboration spaces typically synchronize manipulation of a synthetic environment in real-time, adding to a heightened sense of *presence* (often referred to as co-presence) between users. More recently, researchers have explored the perception of shared objects that exist both in the physical and virtual environments to increase *presence*. Lee et al. (2016) found that subtle incidental movements of a shared table (wobbling back and forth) that extended across the physical-virtual boundary between a real human and virtual human increased presence.

Interactions with the environment represent the last and arguably the most important spatial interactivity relationship encountered by users in AR/MR. Fully synthetic VR environments strive to emulate real-world conditions as technology allows. Spatial computing allows AR/MR experiences to integrate physical objects and boundaries directly with synthetic content, enabling a distinct advantage — spatially responsive digital interactions with the real-world. Moreover, due to the unmediated element of AR/MR experiences allowing users to see pristine real-world features, AR/MR has the added benefit of a high-fidelity visual backdrop, agnostic of technological constraints (screen resolution, refresh rates); conversely, the ideal realism afforded presents additional challenges and expectations on the synthetic content that is blended in. While challenging, the next section discusses how spatially responsive environmental interactions represent the most rewarding influence on *presence* and immersion in AR/MR experiences.

ENHANCING PRESENCE THROUGH INTERACTIVITY

The term *presence* in virtual reality is often associated with a feeling of "being there" (Witmer & Singer, 1998). However, in AR/MR environments, where is "there"? Generally in AR, the predominant features of the synthetic environment are real-world walls and objects with some synthetic augmentation provided by stereoscopic projected images. So, is *presence* in AR about feeling right where the user physically is? Is *presence* possible in AR? Perhaps AR *presence* is about feeling in place, but in an alternate dimension of the same place. Consequently, *presence* could be defined to follow user acceptance of the synthetic content seamlessly integrating with the physical environment.

In MR, dominant visual features will vary between physical and synthetic environmental features. Therefore, *presence* can vary between feeling where you are physically, or wherever the dominant synthetic features intend to transport you. In the latter, feeling transported to a remote location is referred to as *telepresence*. A term first coined by renowned artificial intelligence (AI) researcher Marvin Minsky in 1980 in reference to remote-access technology (Hale & Stanney, 2015). Today, *telepresence* describes one's feeling of being present in the mediated environment vice the immediate physical environment (Ryan, 1994). Ryan went further and argued that true *telepresence* is contingent upon the unification of immersion with interactivity (Ryan, 1994).

From a *presence* perspective, the more interactivity experienced by the user in a synthetic environment, the more immersive that experience will be (Ryan, 1994). Over and above VR, AR/MR experiences permit another dynamic of interactivity by enabling observable interactions to extend between the synthetic and surrounding physical environment. Moreover, AR/MR HMDs allow users to see the physical world around them in real-time, helping to obscure the medium producing the synthetic experience. Concealing the medium paves the way for a suspension of disbelief required for immersion (Ryan, 1994). By providing for a more interactive and integrated mediated environment, AR/MR has the potential to be more immersive than VR experiences.

Hale and Stanney (2015) proposed that the most important factor in *presence* is the user's ability to interact with the environment. From a *social presence* standpoint, Allwood (2000) considered that the environment one of the four major *social presence* building parameters — including purpose, roles, and instrumentation — that characterizes a social activity. Rafaeli and Sudweeks (1997) proposed that interactivity was associated with "attitudinal dimensions of acceptance and satisfaction." Interactivity satiates the user's desire to accept the AR/MR experience presented as real — despite mediation.

A PASSIVE ENVIRONMENTAL PRESENCE APPROACH TO AR/MR DESIGN

Most AR/MR experiences today simply drop in synthetic content into the user's view, confining spatial interactivity to a fixed point. After the novelty wears off, the AR/MR experience leaves the user disengaged, breaking any sense of *presence*. Deep integration of the physical environment when designing for *presence* in AR/MR delivers a more seamless and believable experience that the user perceives as actually happening to them. Greater spatial integration of the synthetic environment serves to anchor the user's perception of the AR/MR experience. Therefore, synthetic content should leverage as many physical contours (ground, walls, ceiling, background objects) as possible. Computer awareness of the physical environment signals to the user that the mediated environment is aware of the observer's surroundings. By dynamically responding to the user's physical environment, the mediated environment simultaneously acknowledges not only the user's surroundings, but the *presence* of the user themself. Analogous to Heeter's (1992) characterization of increased *social presence* due to other agents interacting with the user, the environment is well disposed with opportunities to acknowledge the user's existence. As a result, the user's self feels further integrated and more accepting of the mediated experience, amplifying a sense of environmental presence and immersion.

Interactivity has been described as the degree to which users "can influence the form or content of a mediated environment in real time" (Steuer, 1992). The aforementioned interactivity types predominantly describe active relationships between the user and the user's surroundings (objects, agents, and environment). Active interactions are purposive movements described by "reflexive and volitional components" (Hale & Stanney, 2015). Active interactions are often viewed through a user-centered lens where direct, physical inputs from the user generate a synthetic output by the mediated environment. If active interactions can be labeled as those resulting directly from a user's will, then *passive interactions* can be characterized by indirect synthetic phenomena and responses not intended by the user. The user still benefits from the resulting interactions experientially, despite not being the direct initiator. Said another way, traditional active interactions occur when the user does something on purpose and the synthetic medium responds — deliberate action, then reaction; *passive interactions* occur whether the user initiated it or not — essentially covering everything else occurring, to include how the mediated environment presents itself to the user.

By enabling spatial synthetic content to *passively* respond to the physical presence of the user and physical surroundings, AR/MR experiences have given rise to a new spatial interactivity relationship altogether agnostic of user intent. This requires a shift in mindset for the AR/MR designer; normally, user interface design is focused on how and to what degree the user can directly interface with objects and agents in the mediated environment. Given these new spatial inputs, AR/MR design has expanded into a new dimension of interactivity requiring new perspectives and strategies that are holistically environment-centric, versus solely user-focused.

The concept of "self-extension" establishes that an individual's self-identity is extended to their physical surroundings, to include "body, internal processes, ideas, experiences, and those persons, places, and things to which one feels attached" (Belk, 1988). Slater et al. (2009) invoked self-extension when describing ownership of the virtual body through the use of virtual limbs and bodies to increase *presence* in virtual environments, a psychological phenomenon they called "virtual body ownership". Others have explored self-extension into objects such as robots (Groom, 2010) and a shared virtual-physical table (Lee et al., 2016). Extending this concept to the physical environment of the user during an AR/MR experience, the user's surroundings can serve as an extension of the user's self-identity, creating a form of *environment extension*.

One of the means for establishing self-extension is through "contamination" where proximity to other physical phenomena can result in extension of self-identity (Belk, 1988). Belk (1998) described contamination as a passive, unintentional form of self-extension that can manifest itself when someone feels nostalgic about one's possessions or shows reverence for historical artifacts (Belk, 1998). Applying this concept to synthetic environmental features, AR/MR content spatially integrated with the user's physical surroundings can serve to contaminate by proximity as well, contributing to a heightened sense of ownership of the hybrid environment and subsequent increase in *presence*.

Operationally, the DOD can expect enhanced user engagement and more intuitive interfaces for tactical environments. Seamless integration of critical digital information allows the DOD operator to "off-load cognition into the environment" (Benyon, 2012). Offloading cognition for DOD operators through spatially- and contextually-relevant synthetic cues frees up critical mental energy to focus on time-sensitive tasks during training and operational scenarios. In the context of DOD training, learning environments seeking to reach an affective medium should be able to provoke different emotions from the student. Interaction with the medium's contents is critical to eliciting that emotion (Riva et al., 2007). By exploiting immersive AR/MR experiences by way of passive environmental interactivity, the DOD can garner better learning outcomes through an improved affective training medium. In 1960, Cicero proposed the creation of higher levels of acceptance through interactivity, resulting in "well-disposed, attentive, and receptive" users susceptible to persuasion (Carnegie, 2009). Passive environmental interactions uniquely position AR/MR training environments for enhanced persuasion and acceptance of their mediated surroundings, allowing users to feel more present and immersed than ever before.

OPTIMIZING FOR PASSIVE ENVIRONMENTAL INTERACTIVITY

Borrowing from architectural design, AR and MR designers have typically leveraged interface metaphors or design patterns to develop entertaining AR/MR experiences. Interface metaphors describe the everyday intuitive interaction mechanisms (e.g., scooping, tilting, turning) that can be used to connect physical object manipulation (input) to synthetically generated content (output) (Billinghurst et al., 2015). Design patterns are another commonly used interface design approach where each pattern seeks to capture a solution to a particular design problem (e.g., technology seams, motion sickness) to make the user experience more enjoyable and intuitive (Billinghurst et al., 2015). However, most metaphors and design patterns are generally focused on active inputs from a user versus more passive interactions. Given its nascent nature, AR/MR experiences are deficient in fully developed design patterns and interaction techniques specific to this new medium. Moreover, interface metaphors and design patterns specific to passive environmental interactions and increasing user *presence* have had even less exploration.

Assuming active interactions have been largely exhausted to date, optimizing for passive environmental spatial interactions are of primary focus here. For any DOD simulation or training application, all passive environmental interactions should follow predictable physical phenomena. If synthetic content is depicted unrealistically, users will experience a discontinuity, or “shock” perceptual opportunity in the seam between the physical and synthetic environments, jarring their sense of immersion in AR/MR (McMahan, 2003). Beyond physics, spatial content should be diverse and seek to engage the user. Unexpected synthetic responses such as enabling interactions beyond a physical contour or revealing a hidden room provide users a “surprise” perceptual opportunity that attracts their attention by tempting the user to further interact with the environment (McMahan, 2003). By offering unpredictable, highly interactive environmental details and responses that are logically grounded in physics, AR/MR environments can deliver a higher sense of control and *presence* to the user (McMahan, 2003).

From this conceptual framework, multiple passive environmental interaction strategies are highlighted and proposed below. In all these cases, the synthetic environment autonomously interacts with the intrinsic physical environment, agnostic of user inputs. The user still benefits from the resulting interactions experientially despite not being the direct initiator or constant focus of the interaction.

Figure 1. *Tunnelling* and *Extruding* Interactions Observed in Microsoft’s HoloLens 2 Game

The *tunnelling* interaction uses the physical surface of the room’s walls as the primary input, allowing synthetic content to traverse from one end of the cavity to the other. *Tunnelling* interactions can also occur from floors and ceilings as well. Common tunnel concepts can include everyday doors and hallways. In Microsoft’s Hololens game *RoboRaid*, alien robots appear to break through the actual physical walls of your room to attack you as you shoot back and maneuver about the room to dodge their projectiles (Figure 1). Microsoft developers have described this type of spatial integration as “World-scale” (Microsoft, 2019).

Global interactions comprise of synthetic environmental features that are reactionary by nature and will generally cover physical phenomena informed by physics such as gravity, parallax, occlusion (especially between synthetic and real objects), shadows, and reflections (to include synthetic object reflections). Spatially coherent interactivity between the user and the synthetically-modified physical environment will further amplify a sense of *presence* in the mediated environment. As an example, synthetic burning and the spread of that simulated flame is a *global* interaction that can be designed to “burn” both real and synthetic objects. *Global* interactions help to enhance the user’s perception of the mediated environment as real through deep spatial integration of real-world physical phenomena. That said, real-world physical phenomena chosen for a specific AR/MR experience are not confined to the immediate physical environment. For more whimsical or targeted AR/MR experiences, synthetic content can be designed to follow physical dynamics expected in outer space, on the moon, or under water.

Windowing is another form of passive interaction that has its roots in classic graphical user interface design. As the name implies, it simply utilizes a synthetic window or aperture to allow the user to observe outside the physical limits of the room. Conversely, *windowing* allows synthetic agents to observe inside the room. Window shapes and details can go beyond those found in standard personal dwellings. Synthetic content viewed through the window can emulate the immediate physical environment, or another landscape entirely.

Extruding can be used to add spatial depth beyond the physical constraints of the user's environment. By synthetically pulling the walls or ceiling of the room outward, taller and wider AR/MR experiences are possible. *Extruding* a ceiling could be used to produce the sense of being in a tower. *Extruding* a wall could be used to emulate officemates sitting at their desk in the next cubicle or sitting in the same conference room during mediated telepresence conversations.

Extruding is another passive environmental interaction encountered in RoboRaid. The main intent of firing projectiles is targeting enemy robots. However, stray synthetic projectiles will contact the physical walls when they miss their intended robot enemy targets. RoboRaid will emulate structural damage to the walls (see Figure 1) made by the projectiles and reveal spatially rich synthetic content (wall studs, wiring, pipes) behind the wall, giving the illusion of added depth to the room. Minecraft Earth most recently used this same methodology on a mobile AR platform to emulate game play below the Earth's surface (see Figure 2).

Figure 2. *Extruding* Interaction Observed in Mojang Studio's Minecraft Earth Game

When synthetic content is constructed on top of the floor inside or ground outside, this interaction is called *constructing*. In this case, the interaction uses terrestrial features of the user's surroundings as an input for synthetic content to build on top of physical foundations. Real-world terrestrial inputs can stem from the immediate surface the user is standing on to more distant ground features. Minecraft Earth showcases this technique in Figure 3 where a synthetic building has been *constructed* on top of the Earth's surface. One could also *construct* a synthetic portal or gateway in the middle of the ground to complete the narrative of an isolated door that leads the user to an alternate version of the surrounding space.

Figure 3. *Constructing* Interaction Observed in Mojang Studio's Minecraft Earth Game

Fixtures are observed when synthetic content is affixed to physical walls, objects, and ceilings. *Fixtures* use real-world surfaces as inputs to determine spatial placement and orientation. The resulting synthetic content appears temporarily or permanently attached to the surface. Microsoft has used the term "surface magnetism" to describe similar mechanics when placing holographic objects on to walls (Mircrosoft, 2019). *Fixtures* can range from signage (also known as "billboards" or "billboarding") and control panels, to artwork and chandeliers. Augmenta's SmartPanel *fixture* (see Figure 4) is an AR software defined interface capable of monitoring and controlling industrial equipment (Kovalainen, 2020). Synthetic control of the physical environment can also manifest itself through simple tasks that leverage eye tracking or hand gestures to turn up the volume on a TV without a remote or scrolling through a document without a mouse. From a security perspective, physical access to residential or commercial properties could be regulated through AR devices, enhancing security through obfuscation and supplementary biometric safeguards. Spatially anchored signage *fixtures* can also be utilized as prospective memory aids to help remind the user of information relevant to a particular room or reveal spatially aware insights during task execution.

Outside of structural environmental interactions, some passive interactions arise when the environment responds to the actual presence of the user or other agents. Instead of the synthetic content attempting to augment the structure of the AR/MR environment, these environmental interactions react passively to an agent's physiological inputs. While dependent on agent input, this category of environmental interactivity remains passive based on the volition of the user. The agent's action or presence may have been causal to the environment's reaction, but not the main intention behind the act itself.

Figure 4. *Fixture* interaction observed in Augmenta's SmartPanel Design

Figure 5. *Imprinting* interaction observed in Yahoo Maps' AR Application

Imprinting interactions can occur when the synthetic environment spatially responds to hand or foot contact by an agent. Each time an agent touches something or takes a step, the AR/MR environment reacts either aurally, visually, or in cooperation. As a result, the agent may hear their own footsteps or see where they have previously touched or walked. Aural *imprinting* interactions can be used to simulate sticky walls and floor, or echoes from walking through a large, cavernous space. Visual *imprinting* can be exploited to mimic muddy hand and shoeprints, or pressed footprints on a sandy beach. While not representative of actual footprints made by the user, a rudimentary example of *imprinting* can be observed in Figure 5 to illustrate the concept.

Ma (negative space) interactions are spatial activities occurring in localized air volumes. The Japanese architectural and cultural concept of *Ma*, translating to "space" or "emptiness" in Japanese, celebrates the gaps between structures and relishes the possibilities afforded by that negative space. *Ma* interactions emulate environmental changes due to obstruction from, or movement by, objects and agents. As an object or agent moves through a space, synthetic content filling the air around them spatially responds to the dynamic changes. Some have proposed using a real-world fan to sway synthetically generated curtains to increase *presence* between a user and virtual human (Kim et al., 2018). Manipulation of the synthetic air environment may also include synthetic rain (see Figure 6) splashing on contact with real-world surfaces, synthetic smoke vortexes swirling as a user passes by, or seeing one's breath in a simulated artic setting. Further, AR/MR experiences have the added burden of accounting for unpredictable agents that enter the user's air volume and field of view. These technical burdens are also *Ma* interaction opportunities for spatially integrating their effect on existing synthetic content to create a seamlessly integrated AR/MR experience.

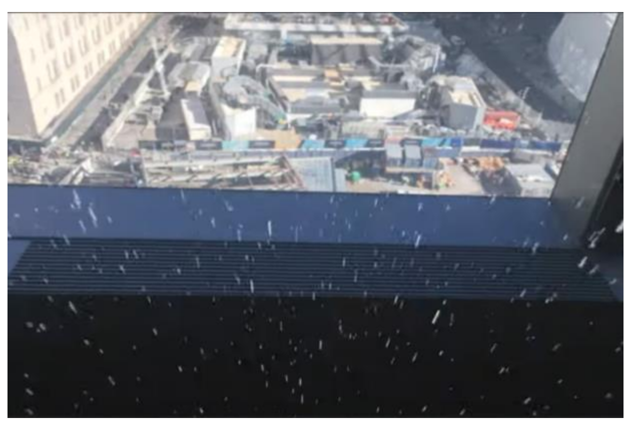

Figure 6. *Ma* interaction observed in Augmented Theatre's Rain Demo

Fusion interactions encompass a category of environmental observables typically imperceptible to the unaided human eye. AR/MR environments not only enable layering of spatial audio, but they are also capable of visually representing those sounds as waves reverberating from their source. Similarly, for physical phenomena outside the visible spectrum, AR/MR experiences can be filled with visual representations of electromagnetic wave propagation. Beyond seeing wave energy normally invisible, *fusion* interactions can be used to see the world through those same bands of the electromagnetic spectrum to simulate 'X-ray' or night (infrared) vison. Depending on available sensor inputs, *fusion* interactions may not be imitations at all, enabling night or thermodynamic (heat) vision enhancements in real-time for a DOD operator.

CONCLUSION

Ultimately, holistic spatial integration simply completes the narrative. Synthetic content cannot just appear; a story laying out where content came from, what it can do, and where it can go is necessary for the story to be believable. Designing for presence and immersion in AR/MR comes down to aligning the user's perception of the mediated environment to the user's expectations within the constraints imposed by the physical environment. The more seamless synthetic content integrates with physical content, the more transparent the intervening medium becomes, leading to acceptance of the AR/MR experience as actually occurring. In the real-world, humans use all the senses available to them to experience reality. AR/MR experiences should endeavor to emulate this multi-modal approach to blur the seam between the synthetic and the real environments, to include spatially aware sound and haptics. Interactions with the environment activated by eye tracking, voice commands, breathing, body gestures, heart rate, and brain activity should also be considered in offering a holistic, polysensory experience to pull the user into feeling present in the new environment. The more invisible the medium used to produce the synthetic experience, the more "immersive, polymodal and polysensory" the experience becomes. (Civitarese, 2008)

A sense of presence and immersion is psychological after all. Presence in AR/MR has less to do with where you are, and more to do with how you perceive the experience. Therefore, definitions of presence and telepresence should not be confined to location and feelings of just "being there". Presence should be defined as a state of being. If there is a need for defining where, presence in AR/MR should be a feeling of being in the mediated environment where the user accepts the experience for what it is — a new hybrid reality. Focusing on active interactions can help the user believe that what they are doing is real. Passive interactions will help the user believe their reality is real.

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