Temporal Telepresence: Immersive Interfaces for TeleAbsence

by

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Abstract

To store the past in a simulation may enable greater understanding of ourselves, our stories, and our histories. The urge to capture our past into networks of photographic, written, filmed, and object-based narratives has long been a means for individuals to identify change, growth, and gain perspective on themselves. Using a dataset of human narratives derived from records and ephemera, this thesis explores a novel approach to preserving and interacting with memories. We present an interactive system of objects and applications that supports intergenerational memory preservation by enabling individuals to actively explore the relationship between personal artifacts, photographs, the spaces of their past, and their memories. This system integrates personal digital twins, photogrammetry, Gaussian splatting, and tangible interfaces to create a new way of experiencing the past, based on interactivity with architectural artifacts and simulations from an individual's life. Using an iterative participatory design process, we developed a set of multisensory interaction experiences that allow individuals to explore their relationship to autobiographical memory. The system dynamically links autobiographical memories with the environments where they took place, responding to text, photo, and object-based interactions. This experience invites individuals to modify their recollections by exploring how photo, video, and 3D space relate to the experience of revisiting narratives from the past. Applications of this system include assisting with dementia, aging, memory loss, and Alzheimer's. Our initial studies were promising. When using the simulation system, individuals spent more time reminiscing, discussing more memories, and experiencing greater presence in their recollections than without the interactive paradigm. The system also encouraged family members to reinforce their memories by actively re-encoding them through the simulation interfaces. Results demonstrated that presence in memories seemed more vivid, detailed, and spatially accurate than before the intervention. The result is a new memory-sharing experience that benefits individuals and families by allowing them to understand how their interactions with the past can be enriched through the integration of artifacts and simulations that impact the development of autobiographical memory.

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1. Chapter 1: Introduction

When we see old photos of our family or ourselves, it is easy to think that they are not really us or our loved ones, that they are not ourselves or our family. Old photos may no longer resemble us at all. We may quickly realize we are significantly different than how we once were. This is because ultimately, all photography is a form of simulation, a representational model of reality we use to capture and represent a version of real experience. In my mind, there are carpeted basements perhaps I have never been to. Places I imagined in novels that were so real, or televisual, or just imaginary, that I feel I could have been there when I was younger. These places are sometimes conjured when I think of other people and who they might be. They are not memories in the traditional sense- they are memories of my imagination. I imagine places to imagine people, to create genre, story, and projection about what might happen to them, who they are- what it means to be someone to begin with. I like to imagine the past lives of the people I love. I like to visualize and remember them to try to understand who they are, or to enjoy who they are. I like to do the same with people I know now. When people tell me about themselves, it's like a personal theatre just for my imagination, a wonderful novel, a personal virtual simulation of what it's like to be someone else. The imagination is a form of augmented reality, letting me see in front of me places and people in my life who aren't there. How can augmented reality and virtual reality enhance our sense of self and others? Real empathy, not artificial empathy, lets us trade places with each other, to see the same view.

Now, thanks to contemporary capture methods, my imaginary memories are in high resolution. Google Earth, once a photographic model of the planet, evolved from being a traditional 2D map into a three-dimensional topographic simulation of the world. This simulation of the planet, due to privacy, is emptied of the human identity of those who were present during the capture, reduced to blurs in the panorama. Gamified and interactive like a spatial playground,

Figure 3: Marcie, a participant in the study, in the Jefferson Drive Simulation

the world is now rendered as a space simulated, indexed, and interactive. But Google Earth, famously indebted to the Media Lab project Aspen Movie Map, is just beginning. What will operating systems for our experiences look like? As extended reality technology evolves, the mapping and three-dimensional visualization of ourselves, our lives, our interior spaces, and even our futures becomes more of a likely eventuality. Head-mounted displays like the Meta Quest and the Apple Vision Pro dynamically capture our personal and intimate spaces, creating three-dimensional maps of our surroundings in mixed reality. With this in mind, this project forges a vision for a future where we will travel through simulations of our life experiences, with the potential to augment and alter our experience of our past history, in the same fidelity as the multi-dimensional planes of Google Earth. Like the film 'La Jetee', we will be able to revisit our past and reimagine our future, infinitely mirroring our experience in simulations of our selves.

2. Chapter 2: Background

The art film 'La Jetee' (1962), presents the viewer with an unusual and paradoxical story. The artfully told short-form narrative, depicted in the moving image while only told in still photography, articulates a future where the planet earth has descended into dystopia. To revive society, future governments design a technology- in particular, a type of head-mounted display- to send individuals back through time, where these 'emissaries of time' are tasked with observing the past so that they may recreate it in the ruins of the future.

One of these emissaries, the main character depicted in the film, was forever traumatized by an experience he had as a child, where he witnessed a man being murdered. When he is sent back to this moment from the future, he sees himself as a child in the past, witnessing the murder on loop. It is only at the end of the film that we discover that he was in fact seeing himself as a double- a version of himself sent back from the future to the same point in the past. We discover that the man- as a child- had witnessed his own death. La Jetee proposes a theory of time, and in doing so, a theory of identity and self that clashes with our conventional assumptions.

'La Jetee' proposes two future-thinking arguments- 1) for the potential of simulations- the idea that a virtual passageway could connect us to the past- as well as 2), an argument for the idea of being othered by oneself, to be able to see yourself in your life simultaneously 'twinned' in a virtual projection. It is this othering that conjures the impetus for this thesis, the experience of time and space outside of one's perspective- through the eyes of an agent, an avatar, an other. Importantly, the time travel depicted by the film does not happen in tangible reality, but in fact happens only in the mind and memory of the subject.

Another compelling historic work of fiction, the 1942 novella by EM Forster, "The Machine Stops", [1] imagined a similar future dystopian world where humans live underground, communicating with each other across vast distances through a shimmering 'blue plate'. This allegory for the future is centered around a mother and her son, who communicate their longing and antipathy towards the "machine", an entity that encompasses the earth. In this dystopian future, tensions between the digital and the physical have resolved into the dominion over humankind by the machine. "The Machine Stops" uses this dystopian setting to illustrate the potential of remote telepresence, which at the time was pure science fiction. Taking cues from both the blue plate, a shimmering vehicle for presence in 'The Machine Stops', and the bandaged head mounted display used as a vehicle to travel to the past in "La Jetee", the works discussed below each consider how technology can be a medium for communication and telepresence into the past and with distant loved ones.

Two visions in the later half of the 20th century emerged to propose a future where simulated reality and physical reality would converge. The Ultimate Display, [2] an essay by a young Ivan Sutherland, predicted a future virtual environment mediated by the intersection of digital potential and physical matter. The world, simulated, would be reprogrammable and interactive, with all of the material potential of physical world. This vision would go on to inspire notable thinkers such as Masanori Nagashima.

A complementary, but divergent vision, was later proposed by MIT Computer Scientist Hiroshi Ishii. Ishii's vision, instead of relying on the simulated virtual environments proposed by Sutherland, Ishii instead foresaw a future where all physical matter is in some way actuated, with the potential of digital manipulation inherent in everything we touch. Applying this method to telepresence, the idea of tangible telepresence evolved, demonstrating the potential of interactive actuated tangibles that connect across distance.

Drawing from the vocabularies for interaction provided by the respective research visions of Sutherland and Ishii, this thesis envisions a way to reconcile the potential of the digital with the experience of the tangible, focusing on the vision of TeleAbsence as a strategy for recovering the spirit of computation in an otherwise object-laden universe. Specifically, the projects discussed in this thesis examine and interrogate the experience of interactive simulations and how they can relate to an object-based and tangible world. For example, in a future immersive telepresence interface, instead of telling you about my day, I will be able to remember my day, watching it unfold in a simulation around us. The objects in my room may be co-present, high fidelity seamless shapes, simulating tactility, materiality, and light. We may share in the embodied experience of an integrated codec of space and time, transferred through the air and recreated in full resolution anywhere. What shape will 'place' take, when it is partially digital and partially physical? What will happen to the human imagination when it is rendered? What does memory mean when we will be able to re-experience the past on the fly? These are the questions these projects below set out to answer.

2.1. TeleAbsence

As we age, we constantly change, and earlier versions of ourselves become memories relegated to the past. Naturally, many memories fade over time and are eventually forgotten, but humans have a desire to hold onto memories [Alexander 2002, Waggoner et al., 2023]. Memories serve a purpose not only to emotionally reflect on the journey of life, but also to make enable individuals to make informed decisions based on one's own experience. We define "TeleAbsence" as an exploratory design of Telepresence in the past or with others who are gone, to provide a sense of "being there" with the presence of a lost loved one or a lost period in ones life. For example, recalling the memory of a kitchen where an individual and a loved one cooked and ate together, a library where they read poems together, a seashore where they strolled together collecting beautiful seashells, or a night train on which they traveled together.

Our vision for TeleAbsence considers methods for preserving an individual's inner life to enable pathways for continued bonds to expand beyond an individual's personal experience into interaction design. How you remember someone, through either their postcards, paintings, letters or diaries, enables us to think about how someone experiences the world. How you remember someone could be through a real interaction you had with them, or something he or she left behind in writing, drawing or sculpting, or what someone taught you. TeleAbsence enables us to consider how we could replicate the experience of knowing someone without their presence. Our vision of TeleAbsence is an interpretation of telepresence that, unlike telepresence's focus on asynchronous communication across physical distance, instead addresses emotional and temporal distance caused by the loss or fading memory of loved ones. Our vision of TeleAbsence questions how to be remembered and how to remember, a transcendent approach to HCI to integrate the human spirit with the design potentials of human-computer interaction, evoking ideas like traces of reflection [3] and remote time [4].

Figure 4: An early mockup of the living room of 220 showing the scans being stitched together

2.2. Interacting with Simulations

Because they traditionally rely on live streamed content, current conventional models of telepresence do not enable interaction between the present and the past. Conventional telepresence is largely limited to two dimensional models of interaction. Emotional and experimental mediums have been explored in human computer interaction, using sensory mediums like feathers, scents, and shakers for mood and emotion to be conveyed through visual, olfactory, and tactile modalities [5]. Additionally, the development of devices designed for intimate communication in remote relationships, such as stuffed bears that allow real-time exchange of emotions like hugs [**?**] and gloves for sending and receiving vibrotactile sensations [**?**], pioneered an area of telepresence concerned with sensory modalities that expanded abstract mediums of telepresence technology. These projects prioritized implicit and personal communication over explicit and goal-oriented communication typical in most video-based Telepresence systems.

TeleCommunication with others is located in the communication media that we use to facilitate their copresence. For example, when in conversation with someone through an online application, the memory of the interaction and ultimately, the person, becomes located at the object where the interaction was taking place. Interactions and identities in cyberspace can be expressed in different locations, as the objects that enable these interactions allow for switching between objects and maintaining the same interaction. However, the objects themselves are still the vehicles for our experience of others, enabling us to connect with people across places and time through the wired world.

Fundamentally, human-to-human interaction requires the participation of both parties. Communicating with another person brings both individuals into an active shared space of dialogue. Before the advent of modern telecommunications, individuals had limited ability to feel copresence with others who were not physically present. In the last 50 years, the advent of modern computing has equipped humankind with the ability to send voice, sound, video, and even touch across great distances. Live transmissions and transmissions delayed in time both have the capacity to be revisited and experienced as surrogates of real experiences. Simulations, however, offer unique potential to be dynamic, evolving, and responsive to the user.

The model of human computer interaction studied in these projects posits that simulations of human autonomy (choice, free will, and user-based decisions) drawn from personal experience, individual identity, and the shared social experience of the embodied (object based) world will eventually become media-based interfaces that can co-exist with the physical world through a unified physical/digital operating system. For example, we have already seen Reid Hoffman, the LinkedIn founder, in conversation with himself through a digital twin. Ultimately, our whole life will be populated by digital twins. Starting from the simple premise that a real object, i.e. a bottle in my living room, could interact with a virtual object, (a glass water bottle could be changed into a ceramic water bottle through an augmented reality interface) one can imagine how artificial systems (for example, a simulation of my childhood) could likewise be running in the background, i.e, situated in my current bedroom, miniaturized, generative and ongoing, running as a shoebox simulation underneath my bed. In spatial media, we will co-exist with simulations like we exist in the present with objects. These simulations will occupy our homes and our worlds and have the capacity to feel real.

2.3. Simulation Hypothesis

The study of simulation interaction describes a growing tendency in the early 20th century to design new experiences, algorithms and interactions using earlier forms of human data. Studying our interactions with simulations shows how the relationships we build between simulated life and real life will co-evolve through the interfaces, experiences, and design frameworks that guide the future of our relationships to simulations.

Nick Bostrom's simulation hypothesis conjectures that there could be a future or present when we believe our lives to be real, when in fact, they are a simulation. In the 2001 essay titled "Are You Living In A Computer Simulation?" [6], philosopher Nick Bostrom proposed that "One thing that later generations might do with their super-powerful computers is run detailed simulations of their forebears or of people like their forebears".

Bostrom's Simulation Hypothesis responds to this conundrum by proposing that it is a likely inevitability. Given that recent evolutions in virtual reality point to the eventful likelihood that we will soon be able to experience simulations that are as rich as our reality, what will this future look like for individuals? Positing that there will be a day when my experience walking down the street this morning is in fact a fully artificial reality- what purpose could this serve? What benefit does this give me? What are the repercussions of this on my experience of my self? How may this change everyday life?

The specific questions underlying the projects undertake below are as follows: How do we communicate with others without two way interactions, and what types of simulations can create new ambient interfaces for interaction? How do objects, themselves, foster these interactions? Finally, how can we foster emotional and memory based communication systems that enable vivid cognitive experiences of communication without artificially simulating the presence of another person?

Figure 5: Images that show the eearly history of living in a home

2.4. Context: The Family Home

TeleAbsence interfaces are designed to foster ‘illusory communications’, conjuring the feeling of being there with those no longer with us. To study these questions, this thesis focuses on the experience of time, personal identity, and the objects and places that create the cognitive foundation for memory in order to explore interaction paradigms for studying our interactions with simulations.

The tradition of biography, biopics in cinema, house museums, and amusement parks are all mediums that invite viewers to experience the perspective of another person. In literature, there is a longstanding tradition of work that explores the premise of the ‘simulation’. Virtual reality has previously been used for health and therapeutic applications such as in rehabilitation, specifically for age-related issues such as dementia [7] as a method for immersing a person in a therapeutically significant environment or context. The type of environments experienced in virtual reality have explored a diverse design space, including projects exploring virtual museums [8], apartments [9], libraries [10], and innumerable others.

How do we understand personal experiences through nuanced uses of technology? A number of artists have explored the relationship between image making, time, and place, and how these dimensions interact. For example, Deanna Dikeman’s photo series, described in a New Yorker article, “A Photographer’s Parents Wave Farewell”, [11] describes a project undertaken between 1990 and 2009. Dikeman annually took images of her parents from the perspective of her car, while departing down the driveway, of both her parents standing together. By the last image, the viewer sees that the only remaining subject is that of the house, as both of the subjects had disappeared from the frame. The subjects, once standing, waving- seen on the porch, moved from the home, to the hospital, to the afterlife- the subjects do not persist, while the house still does.

Author Jack Finney proposes the premise of space as a conduit to past time. Finney paints a portrait of a bored 20th century illustrator living in New York City who is approached by a strange man who wants him for an experiment in ‘time’. The illustrator is placed in a room in

Figure 6: Michael Naimark's historic work, Displacements, used with permission by Michael Naimark

the Dakota hotel, hearing the people in Central Park as he drifts off to sleep only to wake up in the 1880's.

First a novel by Diana Gabaldon and later made into a television drama series, a woman in 1945 Scotland is picking flowers when she suddenly feels drawn to a massive standing stone. She touches it - a fierce wind takes her down to the ground - and when she awakens - she is in 1746 - though she doesn't quite know it yet.

Many developments in recent technology have explored how our data and life stories may connect with virtual or artificially intelligent mediums to continue our presence and experience when we are gone. For example, Storyworth is a software platform that enables users to collect stories from loved ones, creating books from their memories and sending them the books monthly [12]. Recently, significant progress has been made in machine learning and artificial intelligence, enabling the generation of realistic virtual humans [?] speech synthesis [13], and character animation [14], such that virtual characters can look and behave in the style of specific persons. Companies such as DeepNostalgia [15], My Heritage, [16], Metaphysic [?], [17], StoryFile [18], and Re;Memory [19] are a handful of the many contemporary companies exploring simulations of the deceased using advancements in artificial intelligence [?]

Copying and replicating reality has been a topic often explored in popular fiction. The 1994 novel "Permutation City" by author Greg Egan [20] explored the theme of living life that is in fact a 'copy' of the original life, through the metaphor of a simulated world. The science fiction novel "The Age of Em" [21] similarly evoked a potential future where individuals can 'copy' themselves into their computers, creating 'emulations' of themselves that they run in order to understand themselves through a virtual simulacrum.

Personal archives symbolize a way for individuals to capture their experience and create tangible, physical surrogates for time. Many have developed unusual methods for archiving and capturing media content from their lives. Marion Stokes, a Philadelphia woman, began taping everything on her television from 1979-2012, eventually creating an archive of 71,000 videotapes [22]. An article titled "Former Pittsburgher returns to buy his childhood home on the North Side" [23],

A 2024 NYT article discussed a project undertaken by Sheila Heti, an artist who loaded 500,000 words from her journals into Excel and sorted the contents into patterns. Heti writes, "With the sentences untethered from narrative, I started to see the self in a new way: as something quite solid, anchored by shockingly few characteristic preoccupations". [24]

Others have explored novel methods for communication and story telling in fictional works. For example, "Griffen and Sabine" [25] is an experimental epolistory novel that uses mail-based interaction as a storytelling method, displaying letters exchanged between the two main characters as the medium for telling a story about co-presence across space.

What each of these projects share is a focus on the self as the center of meaning making in media, as the nature of the narratives in each is the material of human life, shifted, defamiliarized, or otherwise reconstituted into new forms. Future forms of human computer interaction enable the unique potential of experiencing life through mediated mediums such as those foretold in science fiction, enabling individuals to interact with themselves, their past and their futures in increasingly novel ways.

> *"What is wished for here is an externalized memory, outside of the individual, where controlled recollection can be achieved at the touch of a button—not the flood of sensations filling the body and mind like the agony of the totalizing memory beset on the Borges' character Funes, who, after a freak accident, remembers everything, every lived detail of every moment of every day (Borges, 1962)."* [26]

> *"In their view (or rather in the views and practices they criticize), the material world looks like an intentional extension of the mind, a preservation device designed to bring the past to life for future generations or future versions of ourselves."* [26]

To explore these ideas, this thesis explores a variety of approaches to creating simulated experiences of presence in past places, through archiving, storing, and simulating objects, environments and experiences.

Built on the simple premise that by creating a true to life virtual architectural platform based on places from an individual's life, we hypothesised that this would enable individuals to remember actively in virtual environments that harbor strong emotional attachments, creating media from memories by enabling individuals to reaccess spaces cued from their memory associations on the fly. Seeing myself in a photo is inherently distracting or a dead end, because it reminds me of myself, not of time. But seeing specific objects in photos places me back in the context of the experience. After all, we don't really live with ourselves, we live with the world around us. I hypothesized, therefore, that images that emphasize the environment of a place would be more potent memory triggers over time, or, to put it another way, that images with the individuals themselves would be weaker triggers than images focused on the shared environment where others were, for motivating a sense of presence when recalling the past.

Figure 7: Raskar's "Office of the Future" used with permission, showing multiple overhead projectors transforming a workspace. (Raskar et.al, 1998).

3. Chapter 3: Related Work

We are now approaching a period where new pipelines are emerging to enable the rapid production of interactive experiences of real life that accurately convey the complexity of the human experience. As media transformed from the tangible to the digital, from the virtual to the artificial, we have attained new perspectives on human life afforded to us from these dramatic evolutionary shifts.

The projects discussed below draw from the intersection of life-logging and three-dimensional modeling of past experiences, seen through the function of long-term memory. What interaction paradigms can we design that explore themes for TeleAbsence interfaces? In the projects discussed below, TeleAbsence considers the media that forms our memories, used as the datasets explored in each of these projects. While prior work focuses specifically on the definitions of defining reality, immersion, and artificial life, the challenges confronted by the projects discussed herein offer a novel contribution through an integrated approach to each of these areas.

Below, we synthesize prior research to suggest that the future of simulation interaction relies on this hybrid approach- to live with simulations as part of the integrated environment and to exist with the past in the present, and to enable dynamic experiences drawn from the potential of new approaches to mediated interactions.

3.1. Memory

How we define and understand the human experience of memory has changed throughout different definitions in history.

Work in the last two decades focusing on the neurological and psychological components of memory has contributed to new developments in our understanding of the dynamics of neuroscience and remembering. Byrne, Becker, and Burgess (2007) [27] proposed a neural model of spatial memory and imagery, addressing the relationships between long-term and short-term memory, as well as between egocentric and allocentric representations.

Rubin and Umanath [28] proposed a theory of event memory, which they defined as a mental construction of a scene recalled as a single occurrence. This definition of event memory relied on the hippocampus and visual stream as the primary input source for memory. Suddendorf, Addis, and Corballis (2009) [29] explored distinctions between episodic memory and semantic memory. Episodic memory enables conscious recollection of past episodes, compared to semantic memory, which primarily stores semantic content such as facts and larger-scale concepts about the world.

The projects below focus on episodic autobiographical memory as it applies to egocentric and allocentric lived experiences. In particular, we borrow from the idea of event memory by creating one single occurrence that is based on a visual stream as the stimulus for our experimental study, the Jefferson Simulation.

3.1.1. Spatial Memory

Memories have been researched from a spatial point of view, shedding insight into how memories are attached to physical spaces. For example, researchers have developed a mobile application designed to enhance memory retrieval by mapping memories onto the locations where they occurred [30], while others have explored the impact of location-based mobile technologies on the relationship between memory and place [31]. StoryPlace.me by Bently et al. [32] allows anyone to create a location-based story. Their focus on creating accessible interfaces for inter-generational co-creation resulted in a platform for location-based video experiences. Other recent location-based research has focused on memory enhancement through the development of AR storytelling systems anchored to real-world geographic locations [33].

3.1.2. Emotion and Memory

Certain types of memory have been found to incite varying types of emotional and physical arousal. Speer, Bhanji, and Delgado [34] investigated the neural mechanisms underlying the rewarding aspects of recalling positive autobiographical memories. Samide and Ritchey [35] were curious about ‘retrospective emotion regulation’ and interested in how memory can support the regulation of emotions. Their study showed that the reactivation of memories could affect emotion regulation in patients who use memory recall to ‘reframe the past,’ enabling the reduction of emotional impact upon the reactivation of memory in later recall. In their project AffectCam, Sas et al. [36] found that emotional arousal enhances the quality of memory recall for significant events, improving episodic memory recall. Findings showed that emotional arousal improves the quality of memory recall, supporting richer recall of episodic memories than remembering, which had lower affective intensity. Overall, emotion regulation has critical benefits for memory reactivation in long-term memories [37].

3.1.3. Sensory Activation of Memory

Memory is tightly interwoven with experiences of sensory perception, such as auditory experiences, touch, tangibility, scent, taste, and vision. Judith Amores et al. [38] found that olfactory wearables boost memory performance for spatial-navigation tasks. Their study showed scent delivery systems eased cognitive workload and stress, improving performance and recall.

3.2. Related Work in Telepresence

3.2.1. Spatial Telepresence

In their article "AI-driven Family Interaction Over Melded Space and Time," [39] Kang, Kang, and Hwang discussed the limitations of computer-mediated telepresence. They proposed a solution to issues created by distance in domestic environments through a conceptual melding of space and time, introducing two projects to demonstrate their approach, HomeMeld and MomentMeld. HomeMeld employs AI-driven autonomous robotic avatars to simulate cohabitation for families living apart. MomentMeld utilized visual AI to match semantic-equivalent photos, creating interaction topics. Both approaches attempted to create systems that create rich experiences of co-presence, regardless of distance.

3.3. Artificial Life

The field of artificial life is a broad and diverse range of research areas that has, through its development, taken on various definitions. Stemming from the intersection of artificial intelligence and representation strategies for agent design, artificial life has explored issues in representing AI through avatars, creatures, actors and various data visualization techniques. Many prior projects have proposed computational sandboxes of synthetic, artificial actors, discussed in various definitions as agents, virtual characters, and others.

In 1995, Maes (1995) described the burgeoning field of artificial life, which aimed to understand biological life through the creation of artificial life forms. In another influential early work, Tambe et al. [40] provided a framework for developing intelligent agents as part of interactive simulation environments, focusing on their applications in education, manufacturing, entertainment, and training. Over the last two decades, the evolution of this field has explored how people interpret and respond to verbal and non-verbal personality cues in interactive characters

[41], multi-agent story generation systems [42], as well as the development of virtual humans within virtual reality-based training systems [43].

Many contemporary research projects have addressed the challenges of creating believable and effective AI agents in complex virtual worlds, in both 2D environments, 3D computer and video games [44], as well as in virtual and mixed reality settings. In a recent paper, "Generative Agents: Interactive Simulacra of Human Behavior', Joon Sung Park et al. [45] introduced the idea of generative agents, computational software simulating realistic human behavior. Their work demonstrated that these agents, implemented in a 2D interactive environment, exhibit believable individual and social behaviors. While Park's work was focused on a 2D cartoon-like environment, Danry et al. [46] found that realistic AI-generated characters with human-like faces, voices, and mannerisms also have positive applications in learning, privacy, telecommunication, art, and therapy. Research in this area has been further explored through the implementation of AI-generated characters for enhancing personalized learning and wellbeing [47].

Developing virtual characters with artificially intelligent memory to assist with human recall has demonstrated promise for applications impacting mental health [48], wellness, and personal growth. Sieber and Krenn [48] explored how artificial companions with episodic memory simulations had an impact on improving dialogue dynamics between users and artificial characters. These companions were able to comment on past interactions and recall user preferences and interests. Agent memory has also been previously explored through projects that developed memories for artificially intelligent agents. For example, Ho and Dautenhahn [49] developed a fictional life story for intelligent virtual agents, implemented in anti-bullying software designed to foster personal growth. In this system, memories were stored in a database, including an abstracted summary of the event, a detailed narrative description, and a higher level 'subjective' evaluation drawn from the agent's "psychological perspective" of the event's memory. The use of memory in this architecture showed that memory increased the survival rate of the agents in complex virtual environments.

Inspired in part by the field of affective computing, the design of systems with artificial memory has also explored how the simulation of memory may benefit from other human-like attributes in a computational environment. For example, Dudzik et al. [50] argued that mediated interactive technologies should develop artificial empathic memory to support personalizing user interactions. They found that designing empathetic systems of memory simulation could better trigger more accurate episodic memories in relationship to the emotional recollections of users [51]. Yang and Eastman developed a 'human autobiographic memory simulation' [52] designed to simulate human memory in a computer. Their project focused on autobiographical memory structure through a computer-based simulator. A dual memory model of generative agents was proposed by Subagdja et al. [53], which consists of both an episodic memory and a semantic memory, as well as a 'forgetting' process designed to emulate the natural process of forgetting. In an experimental study, they demonstrated that the memory consolidation process improved the retention of meaningful memory and that "forgetting," while commonly thought of as a negative process, in fact, plays a positive role in improving task performance [53].

Finally, recent research has also explored the integration of motion capture coupled with generative behaviors for driving the behavior of virtual characters navigating complex three-dimensional environments. Hanbyul Joo et al. [54] presented LAMA (Locomotion-Action-

MAnipulation), a novel approach for synthesizing natural and realistic human movement in complex indoor environments by employing a framework that incorporated locomotion, scene interaction, and object manipulation.

3.4. Capture Methods

Our experience of the world is fundamentally three dimensional in nature; however, the majority of media interactions have been restricted to a two-dimensional experience of data. Volumetric media, traditionally defined as content captured with stereo 3D camera systems, has become a standard capture medium for representing reality in immersive or spatial media contexts. Recent projects have enabled shared multi-perspective playback of volumetrically-captured moments through augmented reality [55], while others have explored the use of volumetric video to preserve the memories of surviving witnesses to historic events, such as the Holocaust [56].

Prior work applying volumetric capture to extended reality memory systems has explored how mixed reality can enhance or augment memory through experiments that induce memory manipulations in extended reality experiences [57], as well as studies exploring virtual reality as a memory prosthesis [58]. Mixed reality applications have also incorporated a combination of volumetrically recorded content overlapping onto real-time shared experiences in projects like Remixed Reality. An innovative mixed reality approach, Remixed Reality enables users to see a live 3D reconstruction of their environment gathered from multiple external depth cameras [59].

3.5. Lifelogging

Lifelogging is a set of techniques that is part of a larger area of human-computer interaction research broadly discussed as memory augmentation systems [60], [61], [62], [63], [64]. Lifelogging systems function as a form of memory augmentation because they capture large datasets of audio, video, or other data representative of the quotidian daily experiences of individuals.

The field of lifelogging, a set of practices originating within human-computer interaction, involves the continuous documentation of one's life through various means, including wearable sensors, cameras, and other systems for documentation [65], [66], [67]. First developed by Microsoft researcher Gordon Bell [68] as part of Microsoft's MyLifeBits project, lifelogging is designed as a practice that could automate the documentation, organization, and retrieval of information from an individual's life. Bell was inspired by Vannevar Bush's vision for the "Memex" system, described in a seminal 1945 Atlantic Monthly article, "As We May Think" [69]. In the years since, novel experimental approaches to life logging have demonstrated how it can be applied as a memory support system, using the vast repositories of data accumulated throughout an individual's life to restore connections between the past and the present.

In 1993, Mik Lamming and Mike Flynn coined the term "memory prosthesis" [62] to describe memory support systems focused on an individual's environment and activity. Lamming et al. described guidelines for the design of memory systems that can support context-sensitive reminders. As an example of a 'memory augmentation' system, lifelogging has been influential across many areas of research, discussed in detail below.

3.5.1. Support for Episodic Autobiographical Memory

Life-logging techniques have previously been applied to support memory augmentation, specifically to help individuals with episodic memory impairment [70]. One important system, the SenseCam, developed in 2009 by Lyndsay Williams, was a wearable camera with accelerometers and audio-capturing capabilities that was periodically backed up into a storage database for capture. Through experiments using SenseCam, Sellen et al. [71] looked at how SenseCam images facilitate people's connections to their past, distinguishing between "remembering" the past and "knowing" about it, each scenario of which enables a different perspective and should be considered when approaching the development of lifelogging interfaces.

While SenseCam became a significant standard in lifelogging technology, other systems have explored similar problem spaces. Lee et al. [70] described a life-logging system that captures photos, ambient audio, and location data in order to summarize contents as a surrogate memory archive for individuals with episodic memory impairment. Agtroudy et al. [72] investigated how egocentric life-logging photos affect the formation, retrieval, and activation of autobiographical memories, exploring the development of memory-shaping algorithms that accentuate memories on demand to enhance recall. They showed that reviewing life-logging photos influenced autobiographic memory formation and retrieval.

Research on refining meaningful data collection both relies on and enables better memory cue systems to define how specific content triggers recollection and, likewise, why certain content is defined as more meaningful than others. Curious to better understand how individuals define meaningful episodic content in their lives, Wang et al. [73] investigated how individuals characterize everyday activities through an analysis of visual lifelogs captured by wearable devices like SenseCam and Google Glass. This research led to more refined measures for memory cues to extract meaningful content from the large surplus of data captured. Furthermore, Sas et al. [74] explored how memory cues extracted from daily events can support episodic memory recall, focusing on how participants can isolate the meaningful qualities in events from their lives, which can support recall [74]. These works and others have impacted the design of lifelogging technologies for automatically capturing and extracting the best memory cues [75].

3.5.2. Lifelogging for Dementia and Aging

Over the years, technological innovations have been instrumental in facilitating reminiscence and memory support. New systems designed to support the elderly have significantly impacted the development of dementia and improved the quality of life of aging individuals.

Life-logging has been identified as a significant way to enhance the quality of life of elderly adults, enabling them with interfaces and interactive mediums for reminiscing about their past life experiences [76]. Mair, Poirier, and Conway [77] investigated the impact of using SenseCam on the memory recall of everyday events for both older and younger adults. Projects such as Picgo were designed as a reminiscence service for elders, enabling the annotating of photos in order to develop interfaces that triggered memory. The design of Picgo focused on capturing, annotating, browsing, and reinforcing memories in the form of digital-physical scrapbooks for memory sharing.

Lifelogging has also impacted our perspective on the physical and mental health of elderly individuals. Harvey et al.[67] investigated lifelogging technology among older adults to understand the impact of sedentary behavior and its contextual relationships to the physical spaces of older adults. Other work by Lee and Dey [70] examined the effects of Alzheimer's, exploring methods for improving episodic memory impairment to support recollection. In particular, lifelogging has been shown to benefit individuals suffering from amnesia and memory loss. For instance, leveraging technology to revisit past experiences has positively impacted people with memory loss, including elderly patients with dementia [78] [79] vanTeljilngen et al. showed that the review of lifelog images reinforces memory rehabilitation [**?**]. Technology designed for the smart home, like Amazon Echo, doubles as a life-logging system, enabling individuals to record and reflect on their experiences in their home environment [78].

3.5.3. Reminiscence Therapy

Autobiographical memory has been shown to impact the development and strength of self-identity significantly [80]; [81]; [82]. Reminiscence has been defined as "the volitional or non-volitional act or process of recollecting memories of one's self in the past" [80]. As much as reminiscing brings individuals to the past, reminiscing has been shown to help develop future-focused thinking [83]. Significantly, remembering also has neurophysiological effects that can change the body and state of the individual, providing pleasure and reward for remembering, contributing to an individual's wellbeing [84] [85]; [34].

Butler's life-review theory discusses how people revisit past events to review them [86]. In many cases, revisiting places from the past enables individuals to find closure for unresolved conflicts. While initially rooted in research for supporting aging, Butler's theory has proven beneficial across all age demographics, with impacts demonstrating its effectiveness at improving psychological wellbeing, self-esteem, and an overarching sense of meaning in life [87]; [88].

Harvard professor Dr. Ellen Langer is widely credited with significant early work in the field of Reminiscence Therapy. Langer [89] developed an experiment in 1979 to explore the premise of 'Counterclockwise.'

Critically, the intersection between lifelogging and reminiscence therapy has shown that varying methods for representing, storing, and capturing autobiographical content have significant different impacts for creating meaningful, personalized user experiences. A number of personalized reminiscence programs for Alzheimer's patients have explored the application of computer-based interventions [90], [91], [92]. Notably, interactions with biographical materials have specifically been shown to enhance cognitive stimulation for patients suffering from dementia [90]. Sarne-Fleischmann et al. showed that subjects preferred using personal materials to design interactive systems to aid with reminiscence and cognition [91].

Developing co-design sessions with elderly individuals has shown to be a positive step towards improving these research outcomes. For example, Edmeads et al. [92] developed technology for dementia reminiscence therapy through participatory design experiments with participants in an elderly care facility .

Tang et al. [93] developed Memory Karaoke, a tool to support reminiscence in aging individuals through mobile technology [93]. The tool captures experiences and cues to enhance storytelling and memory. Their results demonstrated that Memory Karaoke outperforms camera photography in memory recall testing. Similarly, Rzayev, Rufat, et al. [94] developed Reflective-

Diary, a way to foster human memory through activity summaries. Their ReflectiveDiary app enhanced memory through a combination of data collection and personal reflection. In another project, through the development of 'interactive memories,' Klein et al. [95] showed that the use of reminiscence technology could fill gaps in caregiver interaction, as well as enhance feelings of inclusion, encourage activity, and stimulate wellbeing [95]. Cosley et al. developed a summarizing system to summarize social interactions to enhance episodic memory recall and retention. Their project, Pensieve, supports reminiscence by using existing social media content as memory cues [96] [97].

Kuwahara et al. [98] demonstrated the benefits of a networked reminiscence therapy system using video telepresence to assist individuals with dementia. Gowans et al. [99] created a system, CIRCA, which aided dementia care by using multimedia for reminiscence therapy. Their results showed the system prompted new memories and increased involvement in reminiscence therapy. More recently, Baumann et al. [100] developed the project 'Mnemosyne' to support reminiscence therapy, specifically in residential care settings during the pandemic. Mnemosyne specifically explored the sharing of captured experiences for memory cues in isolated elderly individuals.

Virtual reality has gained popularity as a tool to support reminiscence therapy. Baker et al. [101] explored social VR for reminiscence within the elderly population. They found that design features such as conversation prompts and virtual hologram visualization enhanced the reminiscence process. Alves et al. designed myView [102], a tool to enable non-specialists to develop virtual environments for therapy, enhancing reminiscence and training. They found that VR therapy benefits from using personalized, photo-realistic environments.

"A study conducted by the University of Kent's School of Engineering and Digital Arts found that virtual reality stimulated parts of the brain that were otherwise hard to reach due to illness. By experiencing a series of virtual environments, patients were better able to make connections and recall memories triggered by the visuals provided by these virtual environments. Feedback from the participating patients was positive, and benefits included a better interaction with caregivers, who now knew more about their patients, as well as a boost in patient morale."

3.5.4. Tangible Objects for Reminiscence

Building on prior work that explores how tangible interactions evoke memory activation [103], researchers have explored other techniques for integrating digital and physical data to trigger reminiscence. For example, Alizadeh et al. [104] proposed the term 'nostalgic reminiscence' to describe reminiscence-based design practices related to interactions with technological objects and outdated devices. They describe how nostalgic reminiscence reveals and cues lost interactions when users contextualize objects within specific life stages and social contexts. In a study, participants shared memories related to outdated devices and technology, recalling lost interactions with outdated devices through nostalgically framed narratives. They found that stories about technology contribute to collective identity, as well as encourage a stronger sense of selfhood [105]

Tangible objects have consistently shown to be an effective method for assisting with reminiscence therapy. Studies by Bong Mauber et al. [106] found that tangible user interfaces are more likely to trigger nostalgia and induce positive emotions in the elderly population. Their study demonstrated that the tangible and nostalgic elements of the interface enabled greater ease of use and stronger retention of interest. Yates et al. [107] focused on how objects catalyze surplus meanings and new memory effects. Yates demonstrated how tangible interactions with objects evoke thoughts and memories, while Huber et al. [108] found that tangible objects enhance reminiscing in dementia care. Importantly, they reflected that such systems work best when they offer smooth interactions and avoid overstimulation. Huber specifically found that tangible prototypes like photo cubes and touchscreens enhanced reminiscence-based communication. Haptic dynamics between touch and objects have also proven helpful in sparking reminiscence. Sion et al. [109] explore how episodic memories can be relived and enhanced through vibration and haptic interactions, mapping past experiences to specific vibrotactile patterns .

3.5.5. Digital Memory

Studies have shown that technology-mediated reminiscence therapy provides reflective and meaningful experiences [110]; Thomas and Briggs, 2014). For example, digital photos have been shown to inspire conversation [111] and to facilitate communication between family members [112]. Axtell et al. [96] found that digital picture interactions impact reminiscence and memory sharing. They compared gallery, slideshow, and tabletop designs for memory prompting. They found that different digital interactions affect memory sharing quantity and type. The 'Gallery' format was not conducive to memory sharing. In contrast, the slideshow format prompts more external memories but lacks 'person-centered' memories. Finally, Emobook by Catala et al. [96] was an app for dementia reminiscence that included multimedia life stories. Emobook supports life story workshops with multi-sensory stimuli.

3.6. Digital Twins: Towards applications of digital twins for memory and remembering

In this section, we focus on the field of digital twins, specifically on their application within extended reality environments. Digital twins are digital-physical (sometimes referred to as cyber-physical systems) that bridge physical and digital worlds. Digital twins provide a virtual mirror of physical artifacts and are often designed to link the physical to the digital in bidirectional relationships.

The concept of the digital twin within computer science was first introduced by Grieves [113]. Since the development of the digital twin technique, its application has proven popular in various industries, including manufacturing systems, the management of indoor spaces, as well as the smart home. Digital twins have proven to be particularly significant for developing teleoperation for robotics [114], [115], manufacturing planning, and factory simulations [116]. In 2020, Jones et al. conducted a literature review to characterize the digital twin research area. They identified 13 characteristics of digital twin technology, including Physical Entity/Twin, Virtual Entity/Twin, State, Realisation, and more [117].

Digital twins have also resulted in significant immersive use cases of digital twins in XR settings, emphasizing the importance of creating seamless relationships between virtual and physical models to enhance user experience. Hoffmann et al. [114] focused on combining VR teleoperation and robot mapping to allow supervisors to fully immerse themselves in the environment and control machines remotely. Their study integrated SLAM algorithms and LiDAR mapping to inform the system about the machine's surroundings, enhancing the remote control capabilities of the autonomous earthwork machines.

Digital twins of human beings have been shown to have significant applications across healthcare, mental wellbeing, and simulation studies. For example, Antunes et al. [118] designed an AI-augmented digital twin for therapeutic applications for people with disabilities like cerebral palsy, speech disorders, and Parkinson's disease. They demonstrated that integrating serious games and digital twin technology resulted in a more personalized therapy experience.

Mark Sagar's development of digital humans

Kim et al. [119] presented a novel method for applying the idea of human digital twin strategies to workspaces, with a research project analyzing the digital representation of human workers in smart manufacturing environments. By integrating advancements in computer vision and real-time data from mono cameras and AR Glass, the system captures and replicates human behavior and detailed work actions seamlessly in the cyber-domain.

Digital twins of architecture have been shown to have a significant impact as well. Testolina et al. [120] introduced BostonTwin, a dataset merging a high-resolution 3D model of Boston with geospatial data. BostonTwin created a seamless interface between 3D architecture models and streaming geographic data, enabling large-scale evaluations of the urban environment of Boston with applications in urban planning as well as wireless network development. Similarly, Lin et al. [121] developed UTwin, an urban-scale digital twin of the UT Austin campus, integrating a diverse range of data, including live, past, and future data. This digital twin focused on energy use and was designed to be a comprehensive platform to simulate scenarios about the campus environment. Unlike BostonTwin, UTwin was a smaller scale environment which enabled greater design and depth of complexity in the relationship between the real and the digital. Drawing from multiple data sources, UTwin enables applications in interdisciplinary research. Originally designed to highlight University research and enhance collaboration and knowledge sharing within the academic community, UTwin has many innovative applications. Finally, Jiang et al. [122] designed a digital twin of the Expanded Perception and Interaction Centre (EPICentre) at UNSW Sydney, implementing extended reality to enable immersive experiences with EPI data. The EPICentre digital twin allowed users to interact with the model through various platforms like Windows Mixed Reality, Oculus, or a cylindrical screen. Users could engage with the digital twin through features like movement controls, grabbing objects, teleportation, and real-time biofeedback of electrodermal activity and heart rate. This project was designed to offer a multi-modal introduction to digital twins through immersive experiences focused on their potential as data visualization platforms.

3.7. Computer Vision and Memory

The development of photogrammetry, 3D scanning technology, and depth capture cameras has led to the evolution of new formats for documenting and capturing reality. The future of human life visualization is built on the foundation of the development of imaging techniques throughout history into the present. The physical, embodied experience of life begins as a dynamic, three dimensional spatio-temporal experience of multi-sensory stimuli, and has historically been preserved, imprinted and captured into two-dimensional objects or sequences in the form of photographs or moving images. Processes in photography evolved through the addition of time into the medium of cinema, eventually evolving back into the medium of space through virtual, tangible, and spatial design processes.

Recently, the evolution of NERF [123] and Gaussian Splatting [124] techniques has advanced this discussion to enable the rapid production of complex three-dimensional experiences with low processing restraints and reduced computational complexity. We are now approaching a period where new pipelines are emerging to enable the rapid production of interactive experiences of real life that accurately convey the complexity of the human experience. As media transformed from the tangible to the digital, from the virtual to the artificial, we have attained new perspectives on human life afforded to us from these dramatic evolutionary shifts.

In 2018, Facebook debuted a new feature titled VR memories [125]. An early prototype, VR memories consisted of taking old Facebook photos posted by users and using computer vision to turn them into a virtual three-dimensional environment in which they could step back into and be transported into the space of the image. Although at the time, this was in early development and was not eventually released, the demo has proved influential in related technology for reliving memories and remembering the past

3.8. Contribution

This research project introduces a novel method in lifelogging focused on the capture and representation of three-dimensional memory, utilizing contemporary advances in photogrammetry and three-dimensional image capture techniques.

Figure 8: Media Lab Metaverse

4. Chapter 4: Case Studies

To store the past in a simulation may enable greater understanding of ourselves, our stories, and our past histories. Our project proposes techniques and technologies that will enhance an individual's ability to remember the present in the future, to mourn the loss of time, and to remember and commemorate past experiences. Taking as our source a dataset of human narratives derived from physical records and ephemera, we aim to examine the potential of interfaces focused on the TeleAbsence principle of 'remote time' by creating toy AI simulations of architecture. We present example scenarios that explore generative human narratives through artificial simulations of the past. In each scenario, we are exploring ways to relocate lost spaces and places in a person's life.

As seen in the related work discussed above, our experience of memory has been shown to be activated through objects, triggered by emotions, and spatialized into environments. Memories are integral to aging, the self, and the development of robust AI-driven virtual characters. In the following section, we discuss current, ongoing, and future work exploring the intersection of contemporary user experience design with a variety of innovative interfaces designed to engage with time. Each of the projects discussed below is designed to influence users' perceptions of time and the self, enhancing how we interact with the past and the present, ultimately evolving a vision for new interactive techniques for experiencing the past. Through these projects, we present the results of a two-year survey of memory technologies, including amateur photography, audio recording, 3D modeling, photogrammetry, and Gaussian splatting, reviewing the various applications of each towards memory, placemaking, and presence.

How do we preserve and interact with memory? These projects each explore this question. One approach focuses on preserving tangible elements of an experience through the creation of an archive of personal objects from the MIT Media Lab. Another involves archiving movement and motion through motion capture. Still, another, using polygonal modeling, fosters telepresence in an interactive digital twin of the lab space. Through Gaussian splatting, the environment of the building was preserved to celebrate the history of human interaction in the environment. Finally, a pilot test of these approaches was exhibited at IDEO as a way to get user feedback on the approaches and user experience design. Each of these projects is listed and described below:

i. Please Take Me with You

A system of object correspondence using miniature time capsules based on objects from individuals' labs and work-spaces.

ii.. Media Lab Memory Project

A miniature museum of the MIT Media Lab used to spark reminiscence with Gaussian splatting environments.

iii. Tangible Media Lab Digital Twin

Digital twins to create large scale simulations of the lab.

iv. Deloitte Greenhouse Workshop

A workshop to sculpt 3D models of where you were born.

v. Ancestral Simulations

An interactive motion capture experience visualizing ancestral simulations.

vi.. AmbientPhoneBooth

A phone booth designed to create on-demand spatial audio experiences that transports people back to auditory spaces in their lives while portraying a user's movement in delay.

vii. Personal Virtual Simulations

A study of how personal simulations of our lives relate to design thinking. Projects were executed with Masanori Nagashima, Phillip Beesely, and IDEO Cambridge.

Each of these case studies highlight the need for design approaches that accommodate the varied dimensions of memory, whether in object, movement, sound, or space, facilitating individuals' reflective practices and enabling connections with the past in present environments.

Figure 9: Media Lab Metaverse installed

Figure 10: Select images of the object communication project

i. Please Take Me with You

During the MIT Media Lab Member Event 2023, I launched a project using 100 small cardboard boxes which were hosted on the 3rd floor of the Media Lab. 100 empty numbered boxes were left on the 3rd Floor Media Lab lobby for members of the community to take. I invited Media Lab members to take an empty box and bring it back to their lab, filling it with mementos from their lab space or other objects that described their environment, experience, and research. Participants were then asked to return the boxes to the 3rd Floor lobby, where they were

Figure 11: Three of the object boxes submitted by MIT Media Lab students from things around the lab, designed to create a system for communication between students and company representatives through the small bits and pieces from a person's life

collected, photographed, and finally exhibited during the Member Event on the 6th Floor.

We gathered roughly three dozen finished containers, each of which held an assortment of objects and ephemera from students throughout the lab. These hand-numbered memento boxes (seen in figure 3 and 4) were each designed as a way to capture the memory of objects and environments from the experience of being at MIT in a small, portable container.

Members were then invited to take a box with them when they left Boston, to integrate the parts of the students lives from the desks here in Boston to the desks where the Members worked. To point towards something as simple as the premise of shared belongings, creating the presence of one person in the location of another to a small assortment of objects, this project attempted to foster a sense of closeness between individuals through shared objects. By

Figure 12: A gaussian splat of Kenneth Noland's interior of the E15 Wiesner Bulding Foyer used as an interactive 3D space for the MIT Media Lab Memory Project

Figure 13: E15 after and before

conceptually locating personal space between two locations, this exploration set the foundation for later work in co-located objects.

ii. Media Lab Memory Project

In the Spring of 2024, I launched the Media Lab Memory Project, to support an online exhibition and augmented reality experience of MIT Media Lab history. This project is based on an interactive threeJS online model of the MIT Media Lab architecture, the buildings of E14 and E15, as a portal for documenting and storing alumni's memories and media, resulting in a map

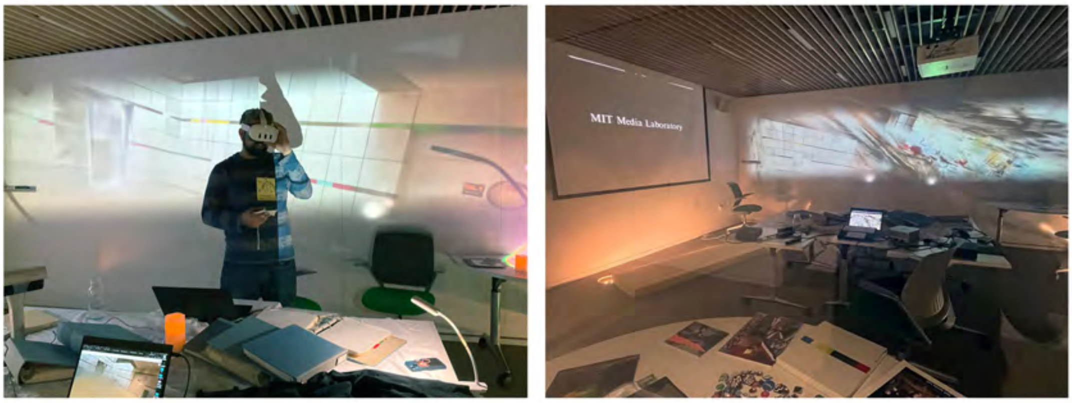

Figure 14: From left to right: our interactive projection of Media Lab history, center: Joost Bonsen and Jon Ferguson, donors to the MIT Media Lab Memory Archive project, students interacting with the mixed reality experience, use of projection and glass to convey a physical space reminiscent of the augmented reality space

of the memories throughout the physical space of the lab as a permanent and augmented reality interface (seen in figure 5).

As we approach the 40th anniversary of the historic Media Lab in 2025, I designed this memory sourcing resource as a way to develop a social repository of memories, stories, and ephemera, an augmented reality archive that will live throughout the space of the building as well as online/IRL as an interactive experience. I created a collection from the archives of Will Glisnes, Joost Bonsen, Rosalind Picard, Jon Ferguson, and others,

The first stage of this project was designed as a website featuring a multi-floor interactive model, acting as an open archive for alumni, faculty, fans, and students to create, add, drag and drop content into the original locations across the architecture of the Media Lab. Once the walls and rooms of the threeJS Media Lab model are filled with photos, memories, text, or 3D objects, the content can then be transposed into an augmented reality application in the actual lab, throughout the spaces of E14 and E15. Any content in the online model will appear dynamically through a visitor's camera throughout the building, enabling a dynamic and morphing AR interface of memories and media to live embedded in a physical/digital twin of the building.

Figure 15: E15 now and then

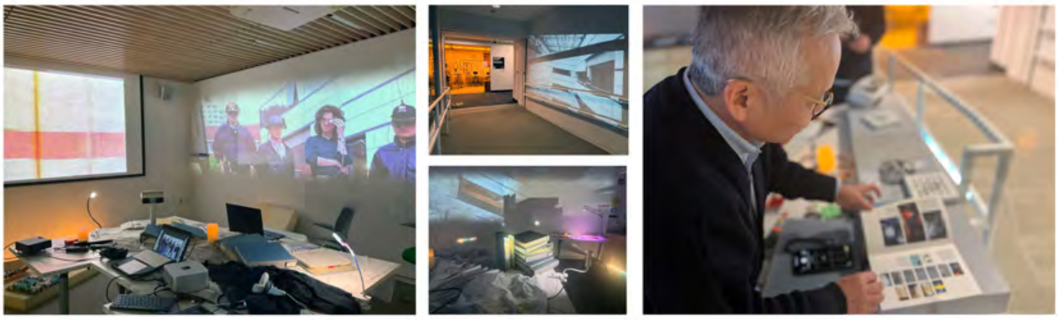

Figure 16: An installation image showing one of several events created to converse and engage with the history of the MIT Media Lab, left to right showing a table covered with collected ephemera and documents, a re-projection of the Wiesner building foyer onto the interior of the new building E14, and an image of Dr. Hiroshi Ishii reviewing Media Lab history

By using an online 3D map of the architecture of the offices in E14 and E15, this prototype allows alumni and faculty to leave memories, photos, and ephemera in the spaces where their memories were cued. Through the use of augmented and virtual reality, this storytelling software aims to enable users to create interactive representations of their experiences for future generations to reflect on. This ultimately will result in an interactive interface that will allow for generative agents derived from the data collected.

To co-design this project with community members, I hosted a series of memory gathering sessions using tangible objects as prompts with Media Lab faculty and students to interact with objects, ephemera, and donate their own personal memories and tangible mementos. One such event, held during the annual Festival of Learning, was an installation with ambient sound, video and virtual reality experiences to encourage memory recall. A second event, held during an alumni gathering during the 2024 graduation, facilitated community conversations to foster a sense of presence in the past.

Figure 17: The final installation of 215 for the user study

Figure 18: From left to right: our interactive projection of Media Lab history, center: Joost Bonsen and Jon Ferguson, donors to the MIT Media Lab Memory Archive project, students interacting with the mixed reality experience, use of projection and glass to convey a physical space reminiscent of the augmented reality space

iii. Tangible Media Group Digital Twin

Beginning in October of 2022, I began a process of 3D scanning photogrammetry models of the Tangible Media Lab, including individual scans of each area, project, and technology on display in the lab space. This resulted in approximately 40+ high resolution 3D scans which each captured the details and structure of over 20 different projects and multimedia objects. I composited a live action point cloud running on three Azure Kinects on top of the polygon-based model environment authored in Autodesk Maya. Each of the publicly facing projects in the Tangible Media Group lab space were also remodeled in Autodesk Maya. The projects focused on are discussed in the chart below, with corresponding information regarding each model.

Next, I developed a mixed reality interface using Microsoft's spatial mapping SDK. This allowed me to capture a full scan of the Tangible Media Lab environment, to be referenced internally by the Microsoft HoloLens to facilitate augmented reality overlay interactions. This mesh was then used by the Spatial Mapping feature to create 'surface planes', generating a

Figure 19: The final installation of 215 for the user study

Figure 20: A screen capture in isometric view of the Tangible Media Lab space

planar virtual space which served as virtual boundaries for tracking content overlaid into the mixed reality headset. The resulting interface connected digital twins of each object and interface in the main display area with physical correlates.

This project was undertaken in order to fully develop a digital twin of the 'Tangible Media Lab', including a portfolio of projects, physical space, conceptual philosophy, and information corpus. By creating a virtual and graphical platform that coexists with the physical space, designed to support the development of a digital twin of the labspace, this project enabled researchers to dynamically ideate, prototype, and virtually experiment with the wide variety of

Figure 21: A Kinect Point Cloud render of the Tangible Media Group lab space

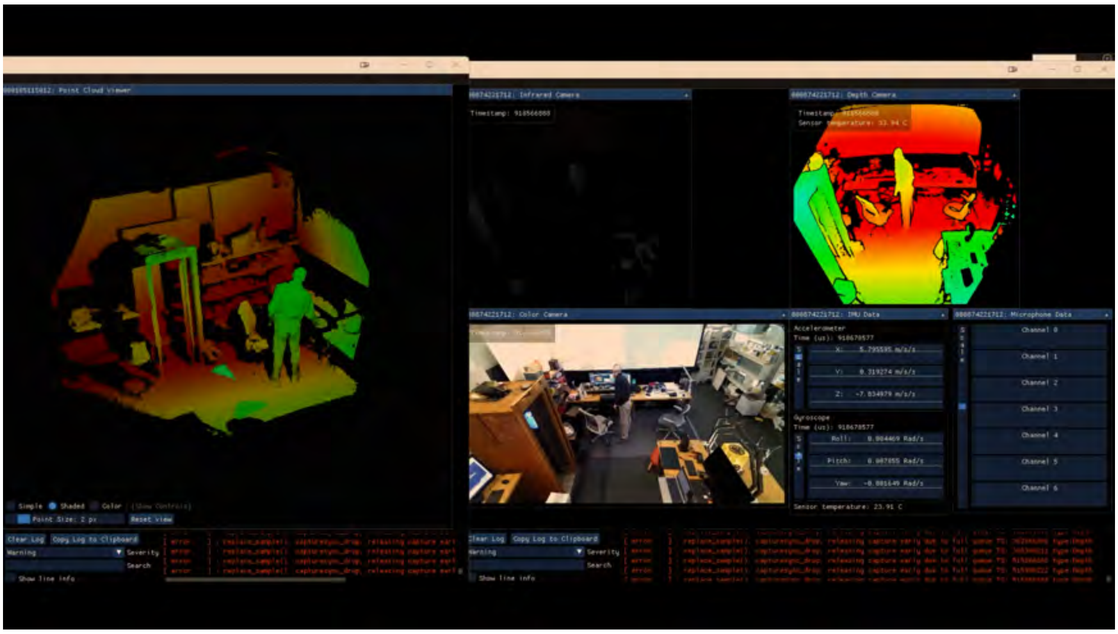

Figure 22: A Kinect Point Cloud render of the Tangible Media Group lab space

research tools at hand in the physical tangible media lab.

For MIT Media Lab Member Event 2023, I embedded depth sensors in the lab that were overlaid onto the three-dimensional object environment. Seen in Figure 12, this created a seamless visual connection between the actuation of the physical objects and the digital twins. Mapping and capturing the motion of users to integrate into virtual object usage will enable a higher fidelity flow between the virtual and the real, and further maintain the seamless temporal congruency between the two. This virtual environment can be like a 'mirror world', a sandbox for inter-relationships between the virtual and the real.

Each of the projects discussed below were recreated as interactive digital twins in an immersive environment:

inTouch

inTouch, a significant Tangible Media interface, demonstrated innovative methods of interpersonal communication through the sense of touch. Utilizing force-feedback technology, inTouch created the illusion of people interacting with a shared physical object despite being geographically separated. This "shared" object establishes a haptic connection between users in different locations, enabling physical expression over long distances.

Transform

Transform merges technology and design, a multi-part shape display that can load and run animations, interactions, and drive dynamic creative input. The installation features three

Figure 23: Render of the TMG lab space simulation/digital twin showing Transform, inTouch, Music Bottles, and other projects on display. A screen capture of the Tangible Media Lab simulation showing the main exhibit space

dynamic shape displays, which move over a thousand pins up and down in real-time, turning the tabletop into a lively tangible display. Live input from viewers, detected by sensors, drives wave-like motions of the pins.

musicBottles

A historic early work by the Tangible Media Group, musicBottles presents a tangible interface that uses bottles as containers and controllers for digital information. The system includes a specially designed table and three corked bottles, each containing the sounds of a violin, cello, and piano from Edouard Lalo's Piano Trio in C Minor, Op. 7. Each bottle is embedded with custom electromagnetic tags, enabling wireless identification.

The system detects when a bottle is opened or closed, making the corresponding instrument audible when its cork is removed. Changes in pitch and volume are visually represented by a pattern of colored lights projected onto the table's translucent surface. This interface allows users to interact with and structure the musical composition by physically manipulating the different sound tracks.

inFORM

inFORM is a Dynamic Shape Display that physically renders 3D content, allowing users to interact with digital information tangibly. It can also interact with the physical environment, such as moving objects on its surface. In video conferences, remote participants can be physically displayed, enhancing the sense of presence and enabling physical interaction at a distance.

iv. Deloitte Greenhouse Workshop

Figure 24: Deloitte Memory Workshop, showing the projection of the MIT map on the Idea Garden workstation, as well as the workshop members showcasing their 3D scanned clay models of childhood homes

During the experimental stage of my research project, I met with representatives from Deloitte for a workshop I hosted at the MIT Media Lab. The purpose of this workshop was to explore how the team could use everyday materials, 3D scanning, projection mapping, and virtual reality in order to feel present in their past. The workshop was focused on how virtual reality enables new forms of telecommunications that enable the sharing of shape and three-dimensional content.

I set up a projection mapping system in the Tangible Media Idea Garden which projected a map of the MIT campus on the Idea Garden ping pong table. This provided a context for the participant's 'present', a scaled projection of their position in real space on the campus of MIT. Next, I supplied each member of the workshop with a selection of playdoh, legos, markers, and other tools. During the workshop, each Deloitte representative was invited to construct a playdoh model of their childhood home, or where they grew up. They did so on top of the table-top projection map of the MIT campus. The table also featured two Azure Kinects arranged on either end. Using the Azure Kinect 3D capture system, the models of their homes located on the projection-mapped table became 3D scanned and re-projected into virtual space. I set up the Varjo XR head-mounted display with tracking cameras around the table. As a result, the subjects were then able to enter the VR headset and change their scale, seeing their renditions of childhood space at human scale within the 3D reconstruction inside the simulation space.

We had 11 participants in total for this workshop session. Each was invited to use a combination of clay, markers, and paper to create a tangible mock-up that depicted where they grew up. By using clay to render memories, we wanted the representatives to explore the shape of their memory, and consider how it would be produced in a tangible form.

One of the representatives used the clay to sketch out the geographic shape of the country where they grew up, not focusing on a dwelling or space, but instead focusing on the overall geography. The 3D scans of each construction were then viewable in the Varjo XR virtual reality interface, enabling the individuals to travel back to their childhood on top of a tabletop projection mapping of MIT campus.

Figure 25: Ancestral Simulation performance as part of Design for the Future, in collaboration with Georine Pierre: Photo credit Doug Seeger

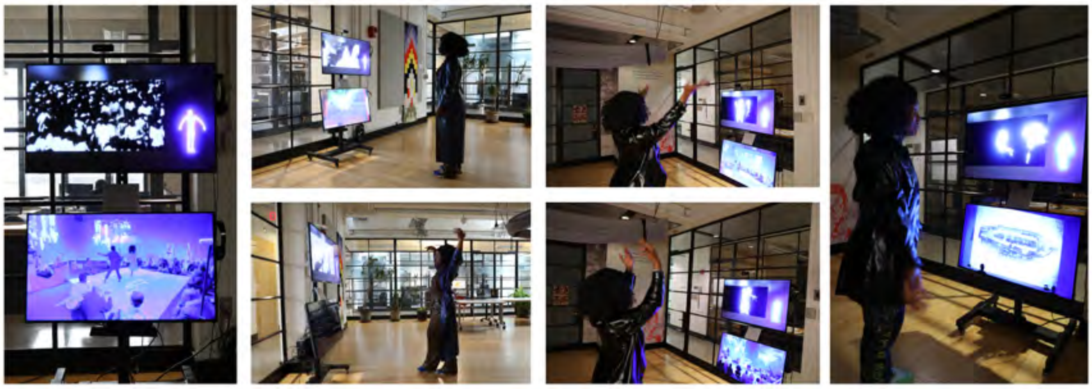

Figure 26: From left to right: documentation of the motion capture environment and performance used for the ancestral simulation, with Georine Pierre shown in the Department of Urban Studies and Planning (DUSP) at MIT in the exhibit space dedicated to Mel King and Tunney Lee

v. Ancestral Simulations

To explore the integration of motion capture and the representation of the body, I collaborated on an interactive and immersive movement-based project focused on creating 'ancestral simulations', a theme I saw connecting with Nick Bostrom's simulation theory concept. This collaboration with Georine Pierre in City Science utilized traditional ancestral storytelling and folklore dance inspired by the Black diaspora to create a system for interactive motion capture.

Drawing from histories and ritual practices around the symbolic function of water, this collaborative project was a motion capture archive that encouraged physical participation to demonstrate how motion can be archived to enable simulations for people to re-experience.

Participants were invited to interact with a series of video/audio works and a collection of pre-recorded rituals (through movement and dance), using their bodies to perform alongside the content. In response to each individual's actions, varying degrees of movement recorded by a Kinect depth camera were then layered on top of the footage. In the exhibit, passersbys were

Figure 27: Interaction sequence, showing MIT Media Lab student Cassandra Lee interacting with the interface. A projection by Georine Pierre onto the hanging modular projection surface designed by Self Assembly Lab at MIT

invited to interact with a video and audio archive and to perform and interact with the motion captured avatar alongside the content through the use of a Kinect. The resulting interaction created a space for memory to be stored in motion, connecting to the prior themes discussed in each other experiment. As participants engaged with the archive, the layering of recorded movements over time developed a new archive. By creating a simulation that evolved from human interaction, this project explored methods for designing 'ancestor simulations' that evolved based on human feedback.

This project was a collaboration with Georine Pierre, featuring Boston-based Haitian folklore choreographer Jean Appolon. As a way to use movement archives to drive simulations, the project explored movement, memory, and sound relative to the historical and cultural significance of water and ritual practices within the Black diaspora (See figure X).

The movement workshop for this artwork included pre-captured movements from professional folklore choreographers dancers Jean Apploilinare that was displayed in the interactive simulation program designed for the installation.

vi. AmbientPhoneBooth

The project AmbientPhoneBooth, a TeleAbsence research project at the MIT Media Lab, explored how sounds trigger memory and simulate the experience of transportation through space by using the communication medium of a telephone as a metaphor for emotionally transporting oneself through time and place.

Developed using an existing phone booth produced by American Telephone and Telegraph Company in 1965, this platform is an artistic installation that merges digital space and physical auditory, visual, and liminal space, enabling the creation of 'remote time' for participants.

An antique black telephone with a rotary dial input is installed inside the AmbientPhoneBooth, sitting on the small wall-mounted corner table. Shortly after the call begins, the soundscape shifts from the phone receiver to ambient speakers embedded in the booth. The experience is

Figure 28: The ambientPhoneBooth in the Tangible Media Group lab space at MIT. Pat Pataranutaporn is featured during an installation using an interactive Azure Kinect based projection. Undergrads from Berklee College of Music are shown prototyping interactions using the Microsoft Hololens

Figure 29: The ambientPhoneBooth being demonstrated using a motion delay projection that mirrors the movement of the user in slow motion in the space. This was designed to showcase how the dimensions of the space allow for a change in the experience of time and movement

intended to convey a feeling of placing a "phone call" to a time and a place, rather than to a remote person.

We chose a phone booth in part because it presents a novel space where individuals are able to be immersed in a private space, despite being in public. This intimacy creates a space where TeleAbsence can be evoked through the immersive interactions of the visitor.

The space inside the booth is augmented to create an immersive sonic experience by installing a set of stereo speakers (on the ceiling) and a subwoofer (on the floor). Although the space is compact, the stereo speakers create a lush and full soundscape. The subwoofer enriches the experience through low-frequency sounds and tactile vibrations, traveling to the human body through the wall. These vibrations allow the booth to emulate a real environment more closely. The subtle haptic qualities of sound around the visitor transport them, as the bumps they feel on a train ride or the vibratory sensation from fireworks or thunder feel real, full, and ambient.

The AmbientPhoneBooth acts as a metaphor for communication across space and time through simple interactions, using the rotary phone as a tangible interaction device. The phone's and booth's electrical wiring are modified to communicate with a modern computer through a serial bus and audio interface. A microcontroller installed inside the phone detects the receiver pick up and hang up, as well as rotary dialing. Each action and event by a user is

Figure 30: From top to bottom: Jacob Collier, musician, demoing the phone booth, interaction design by Ziare Sherman, Jordan Rudress also tested the interface, as well as Marco Tempest. The environment is shown in the bottom most image

then sent to the computer to initialize the interactive experience.

For the demo, we created a heartbeat environment with sounds of a train that took users to a lullaby. A collaboration with Berklee musician and artist Ziare Sherman, this experience immersed viewers into a womb like space that recreated early sounds from childhood, in our demo, focusing on playing lullaby sounds through an immersive audio array.

Figure 31: Phillip Beesley demoing an experience designed for him showing his designs in a mixed reality interface allowing for assemblage, experimentation- Jack Forman, to the right, seen interacting with the Beesley simulator, the Beesley simulator seen on the bottom

vii. Personal Virtual Simulations

As part of IDEO's emerging technology launch, I was invited to exhibit a work-in-progress experience by developing a site-specific installation at IDEO Cambridge. Drawing from the experiments we designed around the AmbientPhoneBooth, I designed an intervention using the phone booth environments at IDEO. There are four phone-booth-like private offices at IDEO that were originally built specifically as architectural interventions to enable privacy.

This site-specific installation imagined the future of the workspace in the era of spatial

Figure 32: Installation shots of Personal Virtual Simulation installation at IDEO Cambridge, showing Paul Knoll from Steelcase. Four rooms were augmented, emptied and reinstalled to create new interactive spatial workspaces

Figure 33: A personal virtual simulation for Masanori Nagashima showing his experience of the Varjo XR and Hololens 2, in which Nagashima was enabled to interact with his CAD system developed in the MIT Architecture Machine Group around 1976 in a Mixed Reality interface through the Hololens 2

computing, mixing VR, projection, and texts by Sherry Turkle [126] to transform the interior of four phone booths. Each booth was designed to create an experience to present a different perspective on the sensory possibilities of office phone booths through this site-specific installation.

4.1. Contribution

Each of these projects above explored how space can enable the transmission of place, through a combination of the storage of objects, the archiving of movements, visualization of memories, digital twins, and immersive experiences of sound. These experiments and related work led to the development of the primary research project in this thesis, discussed below.

Figure 34: The Jefferson Simulation Study, archival photos of the original home taken in the 1980s and found in the basement of the home

5. Chapter 5: Jefferson Drive Simulation Study

> “Our private photo albums—and to the extent that they can be translated into data, our private relationships, gestures, and even desires—increasingly belong to others” (Bahrainian and Crestani, 2016, p. 24) [127]

Reminiscence therapy, a concept popularized by Robert Burtler [128] in the 1960s, proposed that aging individuals could benefit therapeutically from interactive experiences that shed insight on their life and provide introspective forms of nostalgia. For example, interactions with family photos, childhood meals, or technology related to the age of the individual have been found to have a positive impact on the mental wellbeing of the aging [**?**], particularly those with symptoms of dementia and Alzheimer’s. More recently, researchers have shown that experiences with virtual reality have significantly reduced depression and isolation among seniors.

Our approach, seen below, consistent with the design frameworks seen in early teleabsence research, does not recreate lost individuals or feature AI-driven avatars. Instead, past environments are used as interfaces to enable a connection between the present and the past, specifically, through the use of various degrees of the mixed reality continuum: such that the first stage 1) shows the real, present room surrounding the user—with living family members and loved ones—alongside virtual augmented reality images of the past, transitions by movement into the second, 2) showing a virtual environment of the past mapped onto the present, with unaltered original 16mm films embedded into the environment.

By embedding 16mm films (or any family data) into the immersive environment as features of the architectural space (behind windows, under doorways, for example) this exploration highlights the potential of immersive experiences based on real spaces to enable the transposition of past content onto spaces that relate to the original content generation.

By combining techniques drawn from digital twin research, processes in photogrammetry and Gaussian splatting, and theories of presence in immersive media, filtered through the lens of lifelogging and reminiscence therapy, the projects discussed in this thesis demonstrate approaches to preserving memories in objects, simulations, and environments. After exploring object-based memory, tangible interfaces for memory recall, immersive experiences, and digital twins, the final project in this thesis focuses on a convergence of each methodology applied to an extended family of individuals and their memories, focusing on a single house in which all participants spent significant time in their life together.

As a prototype authoring environment for immersive media memory storage, this final section of the thesis details an experiment in a virtual home environment that enables the input and organization of data from an individual's past life into a dynamic spatial simulation designed to support memory recall. We present the results of a study (n = 18) which used a photogrammetric reconstruction of a past domestic environment as a platform for stimulating autobiographical memory.

The Jefferson Drive Simulation is a study of how digital twins and interactive interfaces of personal environments can contribute to studying simulation interaction. In particular, this simulation uses time as a parameter, representing a past place, the lost childhood home of the Dean Family, a Pittsburgh-based multi-generational family. Using a high-resolution photogrammetry scan of their original home—which is now gone, since vacating the home in 2022—a scan was executed over the course of the process of moving out of the home. The interface in this experiment is designed to allow for the reproduction of past domestic environments into one's present environment through the use of mixed reality. By offering a flexible, portable, and repurposable simulation of a past personal space, we explore the implications of transporting place and replacing space across time, through the use of simulated archived environments from an individual's life.

5.1. To Store the Past in a Simulation

The following experiment explores how we can generate meaningful personal virtual experiences that simulate an individual's experience of their past as a way to develop memory aids to support long-term memory recall. One of the goals of this study was to evaluate whether or not experiencing memories in virtual environments enables an individual to re-encode a memory from long-term memory, thereby potentially strengthening its ability to be recalled later or reassessed via memory cues stored in virtual environments. When we re-experience a memory in virtual reality, does the brain re-encode the memory as if it has been experienced in real

Figure 35: Images without human subjects of the family's living room used as prompts in the virtual environment

experience?

5.2. The Dean Family Dataset

Everyday, we interact with images of strangers, friends, family members and loved ones on social media, creating datasets of our personal moments and clicking and scrolling through distant yet intimate experiences. A picture of a person you've met is transformed into a button. Through the advent of social media, the experience of personal media has taken on the dynamics of commercial media. Users can cruise, peruse, channel surf and review memories and photos with the same media interfaces they are used to applying to their interactions with commercial content traditionally associated with television or cinema. As our personal lives become repurposed as media experiences, it is critical to reflect on the impact this will have on memory, human consciousness, and familial connections.

Family archives offer tremendous potential to provide rich datasets for reconstructing cultural heritage and genealogical history. To initiate this project, I developed a digital archive, the Dean Family Dataset. This multi-modal dataset was comprised of photography, photogrammetry scans of the family home, 8mm and 16mm films, home movies converted into gaussian splats,

Figure 36: Video Conversion Dataset collage

and hours of recorded audio. To prepare the dataset, I scanned 5,886 analog photographs. I transferred and re-cut over 40 hours of analog 8mm and 16mm family film and footage. I created meticulous 3D renders of the 11 room house. I 3D scanned hundreds of individual objects- the interiors of each drawer, space, and area in the house. I created panoramic 360 photography of each space.

The analog photographs, taken over a period of time between the 1950s and the early 2000s, documented decades of life in the residential home of 220 Jefferson Drive. The 60 year period encapsulated the majority of most of each of the family member's overlapping life: the early life of the parents, their marriage, early careers, and subsequently the birth, development, and story of their two adult children's lives; as they grew up, matured into adults, and became their own individuals. By organizing these photos around the places they were taken, not chronologically, but instead through clusters of related angles, family members, and spaces within the home, I was able to draw parallels around how photography conveys age, place, and a sense of self over time.

5.2.1. Dataset

The data captured in this project comprises roughly 4 terabytes of space. As an approach to exploring the implications of lifelogging practices in three-dimensional capture formats, the primary medium of the dataset was three-dimensional files in the form of .obj and .fbx with

Figure 37: Side angle showing a simulation with 3D scanned agents navigating the space as part of a prototype authoring environment designed to enable individuals to run simulations of their past

related images and textures. In total, the simulation includes:

- 800+ individual 3D scanned objects
- 18 rooms over 4 floors
- Prototype Authoring Environment
- Spatial narrative media design
- A user study designed to source location-specific memory data

5.3. Installation Design

This study aims to evaluate how revisiting simulated past places may enable a greater sense of the felt experience of autobiographical memory compared to other approaches common in reminiscence therapy. The transmission of personal space through virtual telecommunications media allows for unique instances of co-presence through the extension of architecture across

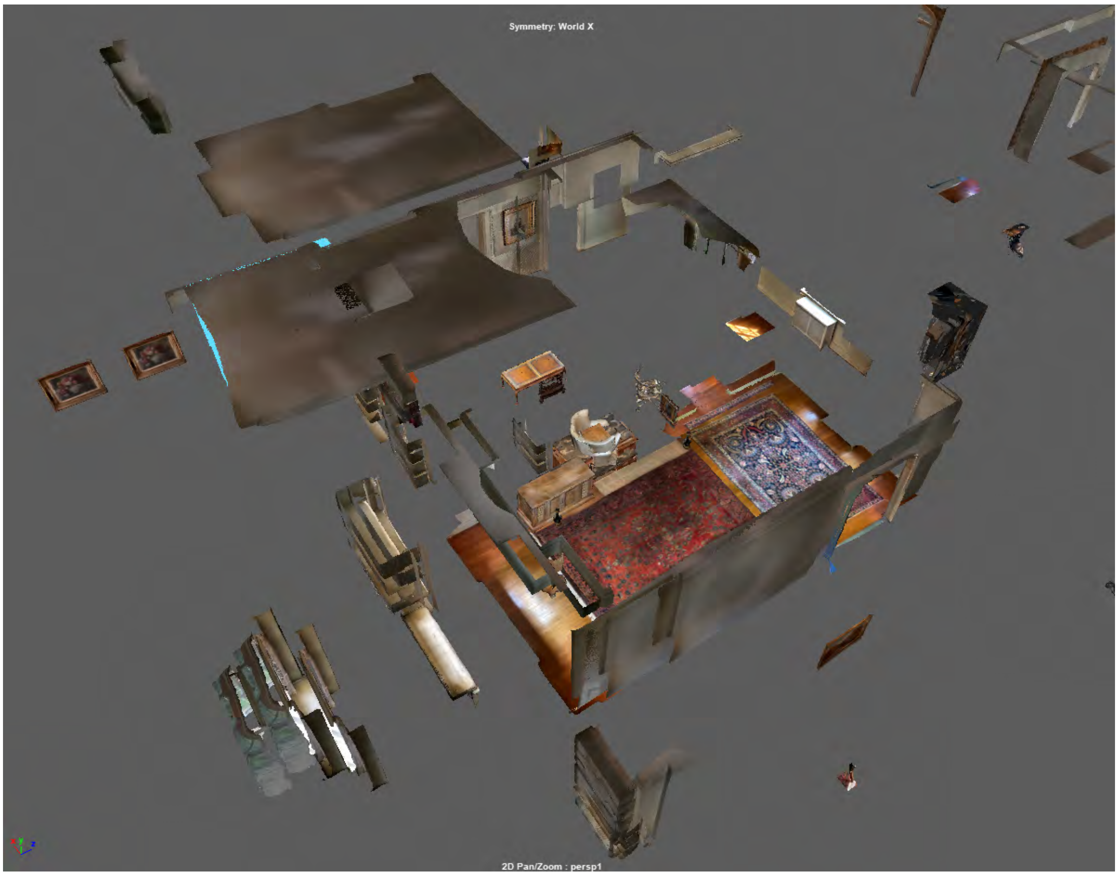

Figure 38: Work in progress shot showing the stitching process used to reconstruct the space at high resolution from hundreds of close up scans

otherwise geographically separated environments. In this study, we explored the transmission of space by occupying a house directly diagonal to the original home. This empty home was used as an installation environment to create a setting for the mixed reality environment and study. By resurrecting some of the traditions and interactions from the past home across the street, a physical simulation of the original home was created. This proxy space captured the air quality, light, and overall mood of the original space, in order to enrich the virtual experience in the space with environmental details.

We started by acquiring access to the house, 215, across the street from the original house, 220. In this controlled environment, we specifically installed select pieces of furniture. The temporary installation in 215 Jefferson Drive of select objects and furniture from the original home, 220, was situated to reflect the inversion of the original space. Meaning, the sofa where the visitors sat in 215, physically, would translate virtually to the inverted perspective they would be viewing of the original home, 220 Jefferson, in virtual space. As seen in figure X

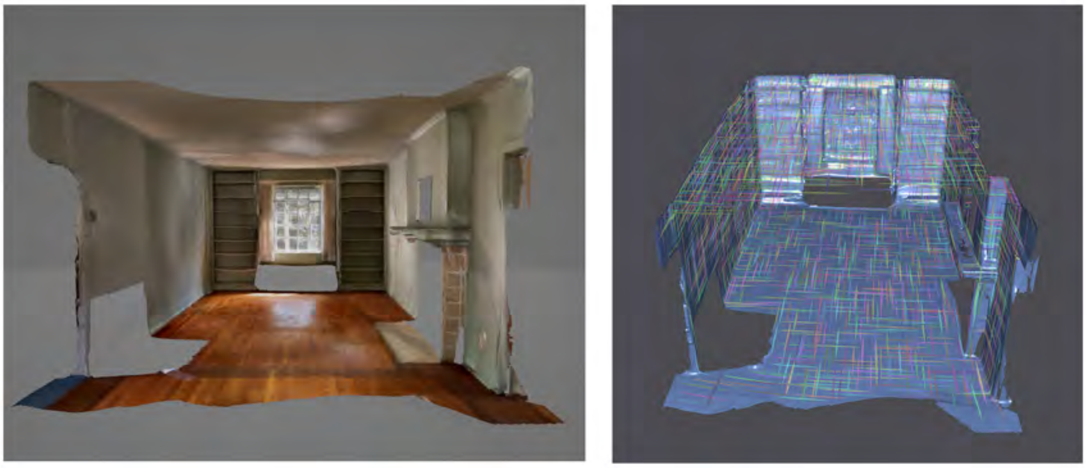

Figure 39: Images showing the reconstruction workflow- image on the left show the interior, to the right shows the interior after being retopologized using the instantmesh algorithm to reconstruct the space while retaining the detail

5.4. Motivation

This project, as an experiment in teleabsence, focused on the development of experiences that create a sense of remote time. Remote time, defined as a core principle for teleabsence, illustrates interactions that cue proustian moments.

In developing this project, there were several core motivating interests that drove our study of remote time. These motivations are organized into three themes below, 1) representation motivation, 2) wellness motivation, and 3) technological motivation.

5.4.1. Representational Motivation

What representational issues do we face when recreating an artificial reality? How will these issues differ when the artificial reality is based on one which was real, personal, and rich with emotional attachment? How can we use environments, sound, documents and related ephemeral material to create the idea of a person, without representing the person themself? Initial experiments in researching telepresence across time used photorealistic avatars to create interactions between the present and the past. However, issues resulting from the uncanny valley led us to focus on representational strategies that do not rely on the body of the individual, and instead focus on spaces, ephemera, and the traces left behind by a person. Instead of avatars or re-representations of the family, we utilized family memorabilia in the virtual environment. Previously unseen 16mm movies that featured the subjects were placed inside the virtual environment to create a sense of remote time for the viewers.

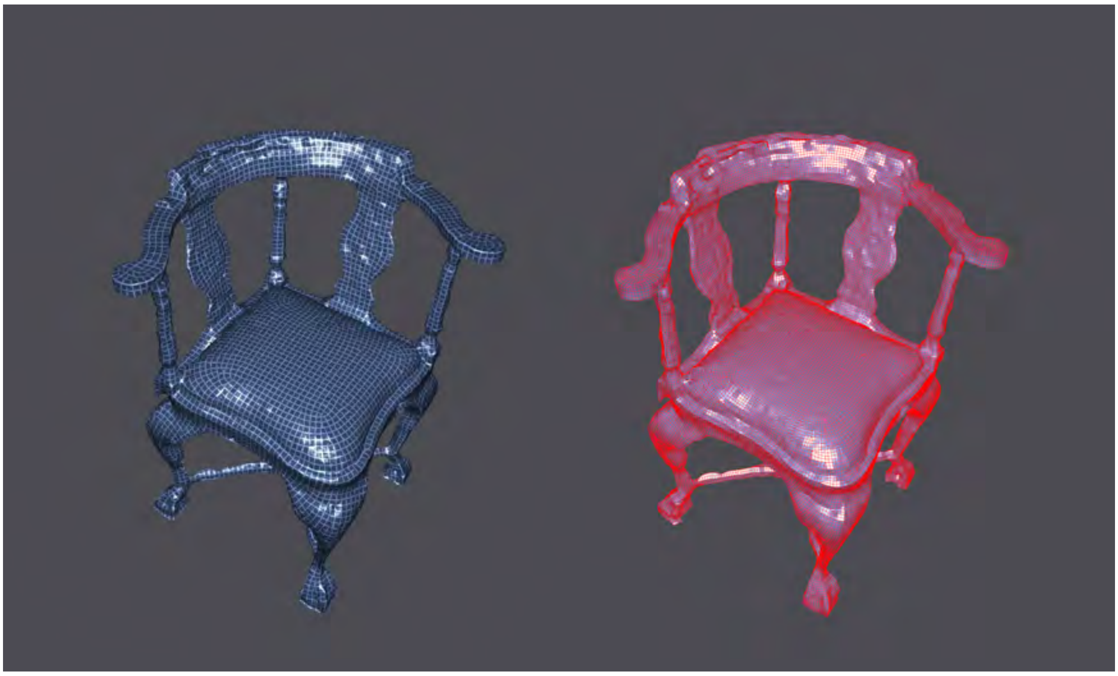

Figure 40: A chair from the scanned dataset, showing the chair in the full mesh with the retopology and the suseqeuent output

5.4.2. Wellness Motivation

Aging is oftentimes accompanied by memory loss. This project offers a practical application of virtual reality to create interfaces for storing memories. We believe that this interface could act as a vehicle for aging individuals to experience past places, interact with family memorabilia, and in turn, provide a resource to delay the loss of long term memory. Long term applications of this project include the re-visitation of recorded memories into long term archives.

5.4.3. Technological Motivation

As image capture technologies become more ubiquitous, reality capture mediums will have faster loading, enabling photorealistic illusions of place and people in mixed reality environments. A technical contribution in this project is the development of a workflow for lightweight high resolution three dimensional scans of interiors for rapid remote loading.

Mixed reality media will soon co-exist seamlessly in anchored experiences over the lived environment. Memories and experiences and full resolution virtual spaces will be anchored to present spaces, enabling us to preserve archives of spaces within them. For example, an individual will be able to project a past place in their life through augmented reality over the location of it in the present. This will enable an individual to ‘see’ into the past, viewing past places in augmented reality overlays transposed onto current locations in the present. One day, everything that happened in a room will be able to happen again.

Figure 41: The final installation of 215 for the user study

6. Contribution

The three main scientific contributions of this project, and its general structure, are as follows:

The first contribution is the concept of in-situ mixed reality memory simulations using tangible objects and photographs as prompts in an interactive system of memory simulation. We describe the setup, important design choices, and implementation details of our mixed reality environment.

The second contribution is to show the technical feasibility of the concepts by presenting a working prototype, deployed in a pilot study with n= 15 users. In contrast to many existing solutions, our system is multi-user capable and designed to be social. Our toolkit runs on one or more Meta Quest head-mounted displays and can easily be deployed in a variety of different environments. However, it is designed to be deployed specifically in a nostalgic domestic environment with accompanying memory cues in the form of tangible objects. The research study includes different technical formats for media (mixed reality, photo-based recall, and an interactive object based toolkit), various interaction modalities (touch, tangibles, spatial input), and both single- and multi-user scenarios.

The third contribution is a preliminary evaluation illustrating how this approach might be advantageously used for assisting with memory recall when applied to elderly individuals. We discuss this by reporting on practical applications of the system with subjects using real data derived from a user study, discussed below in more detail.

Figure 42: Left shows the house at 215 which was emptied and used as a set to reconstruct a mirage of the original home at 220, using furniture, tangible objects, and family heirlooms. The image on the right shows the space after being reconfigured to represent a set inspired by the original home

6.1. System Architecture

This user study was designed with the following system architecture:

1. A high resolution 3D scan of a home that had been lived in for 50+ years;
2. Digital preservation of physical/architectural archives of the home,
3. Full reconstruction of the home in virtual space,
4. The temporary installation of a physical environment in an empty home near the original space,

Figure 43: The environment of the scanned simulation space of the interior of the first floor of 220

5. Remapping of the original home onto the architecture of the reconstructed home through augmented reality,
6. A social experience comprised of 15-20 former visitors and family members to the original home, who were each invited to participate as subjects to re-experience the past place through a mixed reality environment,
7. Nostalgic audio and social dynamics that recreate the aura of the original experiences;
8. A tangible toolkit that contains objects, ephemera, and images that relate to the original space,
9. Emotionally arousing music to assist with memory recall.

6.2. House 1

The following section takes us through both homes by way of description, the original home and the simulated home. The original home is described and pictured as it appeared between 1972 and 2022. The original home has since been sold and renovated. As such, this project represents virtual cultural heritage by preserving the lost state of the home. The installation home, across the street from the original, is described as it appeared as a temporary re-installation during the period of the user study described in this project. The entire home was scanned, but since the study only tool place on the first floor, we are describing the main spaces featured in the study simulation.

220, the original home, is a large two and one-half story center hall house constructed in 1928. Although it is executed in a colonial revival style, the builder broke with that traditional style by facing it with an industrial looking beige-raked brick and steel casement windows. The materials and aesthetics of the home are consistent with it having been constructed at a time when Pittsburgh, PA was one of the world's foremost centers of manufacturing. The front entranceway nods to the colonial era in that it includes a fanlight above the front door flanked

Figure 44: Viewers were able to move between the foyer, the dining room, and the living room of the simulated space

Figure 45: Original Foyer of 220 (now gone) captured with a Ricoh Theta 360 Camera

by sidelights. The front door is designed with three small descending windows in a row, with a brass-plated mail slot that, in the later years, always squeaked when opened.

The fan light and side lights of the front entrance were composed of leaded glass, illuminating the foyer with scattered daylight. Once inside the home, a medium-sized Louis XV style mirror with golden edges was hung over a light blue painted wooden credenza with a cut glass crystal table lamp on top. The first floor opens to a grand staircase, originally covered in bright blue wool carpet along with a rounded wooden railing, ending in a swirl at the bottom landing of the stairway.

The living room to the right of the foyer opens into a deep and wide space with two floor-to-ceiling built-in bookcases. The bookcases, once filled with antique Hummel figurines, stuffed toy foxes, and bisque and ceramic collectibles, held the family's most cherished possessions each holiday. Between the bookcases was a window seat covered in pillows beneath a large, main window, where the sun filtered in through the backyard pine trees. The walls, grey green

Figure 46: Original Foyer of 220 (now gone) captured with a Ricoh Theta 360 Camera

and flat, were broken by a large mantle over a mottled brown tile fireplace centered along the right wall. Hardwood flooring was softened by a patterned coral-colored Sarouk carpet and another Persian carpet with blue coloration covering most of the floor.

At the other side of the front hallway, the dining room opened beyond another rounded arch at the edge of the front foyer. The focal point of the dining room was a large French Provincial mahogany dining room table, seen horizontally from the entrance. The dining room table held a silverplate epergne center piece underneath a six-arm crystal chandelier. Six walnut French Provincial dining chairs with faded dark blue and green upholstery flanked each side of the table. By the front window to the left was a mahogany dropleaf tea cart holding a pair of silverplate four-armed candelabra and a glass cake stand. The dining room flowed into the adjacent kitchen through a swinging door, and on the left side of the doorway was a small wooden silver chest, on the right a seven foot antique French armoire.

6.2.1. House 2

215, the second house, across the street and slightly to the left from the original, is a Tudor revival-style house, built in 1937. The curious interior of the home is coated in an ornately designed stucco plaster, applied in swirly patterns throughout the foyer, spanning most of the first floor and punctuated by heraldic insignia: lions, crests, sailing ships, acorns, Scottish terrier faces and thistles. The texture of the wall matches the texture of the fabric on the sofa.

As one enters 215, the main hallway opens into the large, exposed A-frame living room, with a wood paneled ceiling. Four wide chestnut beams span the room's width, with each beam hiding embedded lightbulbs installed in the upper side, illuminating the ceiling and indirectly, the room below. In the living room, the south facing wall contains a large distinct window with diamond paned leaded glass adorned with large colored glass heraldic elements. The main window is flanked on either side by two smaller diamond-shaped side windows in the same style. The opposite end of the room, across from the front wall, is dominated by a medieval-style stone fireplace, flanked by two inset alcoves with rounded tops and a shallow built-in. Arched

Figure 47: Original Living Room of 220 (now gone) captured with a Rico 360 Theta Camera

Figure 48: Living room of 220 (now gone) captured using Rico Theta 360 camera

openings flanking the fireplace lead from the living room to the front foyer and to the dining room.

6.2.2. Re-installation of Inverted House

For the re-installation of components of 220 into 215, we installed the original American made French Provincial coffee table from the 1950s, consisting of a black veined marble slab resting on a wooden frame with curved cabriole legs. A three-seat sofa, slip-covered with off-white classic crewel work fabric, was placed under the large front window area, centered between two French Provincial end tables. On the end tables was a pair of matching antique French oil lamps made of black porcelain with brass detailing. The lamps, converted from 19th century oil lamps, each feature a small brass turnkey originally used to raise and lower the wick to regulate the amount of illumination provided but were modernized with modern rotary electric lamp switches. The living room floor was covered by two ornately-patterned Sarouk Persian carpets laid lengthwise across the width of the room covering most of the floor. A pair of occasional chairs with saber legs and cane seats, two wingback chairs of indeterminate traditional style and a rounded white upholstered library chair finished out the arrangement of furniture, each piece coming from the first floor of the original home across the street.

6.3. Boxes

As a tangible interface for remembering, I created two tangible sculptures, memory boxes that contained a drawing of the home alongside an assortment of objects and mementos that catalogued the time the family lived there. These two containers were designed as physical books, inspired by the interface of a laptop. The boxes contained decades old wallpaper and carpeting from 215, which retained the odor and scent of the original space, as a method to incite and spark memory in the users.

Figure 49: Tangible Memento Box for 220 using original wallpaper, carpeting, portrait, and found objects and ephemera from the house

A hinged lid opens up to an enclosure hosting an array of objects where, as on a laptop, a keyboard would traditionally be. Instead of a screen, a mounted drawing of the outside of the original home hanging on a fragment of the wallpaper from the original foyer occupied the hinged flat surface of the lid. Symbolically, this represented a digital interface, but with analog counterpoints and components.

Each of the two memory boxes contained objects and materials from the original home. The

Figure 50: Second Tangible Memento Box for 220 using original wallpaper, carpeting, portrait, and found objects and ephemera from the house

Figure 51: Two drawings of the Jefferson house, one with pen, one in watercolour

hand drawn images of the front of the home, one in ink and one in watercolor, were both derived from an original sketch of the outside of the home, in a style traditionally given as a housewarming present in the 1970s.

6.4. Summary of Study Design

In summary, the study design was composed of the following:

Figure 52: Various angles of the memory boxes in the room, showing the hinge, items, interior design, and various textures

Figure 53: Marcie, a participant in the study, showing the interaction sequence of search, touch, and viewing used for looking through the objects from the memory boxes. Each memory box was designed to resemble the interface of a laptop with the idea that the objects take the place of keys and the wallpaper and drawing takes the place of a screen

- An interactive simulation, the Jefferson Drive Simulation, allowing for immersive visualization of past memories. The simulation was filled with personal content to create non-specific memory prompts. Each participant was enabled to interact with the simulation in a specific way based on their own memories and impulses.
- The Jefferson Drive Simulation was comprised of high-resolution photorealistic three-dimensional scans of the original home, 220 Jefferson Drive.
- The virtual home was filled with scanned analog photographs from the original space as well as segments of 8mm/16mm home movies from the original space. The photographs did not depict any subjects and only depicted the spaces, but the home movies depicted subjects, including the subjects of the study.
- Two tangible memory boxes, each containing ephemera from the past home, as well as hand-drawn and watercolored images of the house.

6.5. Study Conditions

This study was designed around a social event, in order to engage the individuals in an active community of friends and family members as a way to introduce the social impact of space as

Figure 54: Demonstration image showing the researcher working with two subjects to set up the immersive mixed reality interface, viewing the memory boxes and the room surrounding them in mixed reality

a part of the study. Importantly, no participant revisited the virtual environment in isolation, doing so instead with the ambient sounds of other family members milling around the house during the study process.

On April 20th, 2024, 18-20 subjects from two closely interconnected families were invited to visit a previously empty house across the street from the home some of them once lived in. The house was decorated to resemble a variation of the original home. Each subject participated in two conditions, a control condition and an experimental condition:

1. In the first condition, prior to revisiting Jefferson Drive, participants verbally described a memory associated with the memory of a lost loved one while alone in their own home, via audio recording. The memory was prompted to relate to a specific room they remembered from an experience at 220 Jefferson Drive. Afterwards, participants completed a questionnaire for presence and vividness of mental visualization of memory. The questionnaire is available in Appendix A-2 and summarized in section X.1. The pre-survey questionnaire was based on the standardized presence questionnaire [129] developed by Slater, Usoh and Steed.

2. In the second condition, while attending a multi-subject study at 215 Jefferson Drive, subjects re-entered a physical space that approximated some elements of the original space where the memory took place (such as elements of the original furniture and spare objects). While sitting on a sofa from the original space, subjects donned the head-

mounted display (HMD). While wearing the head-mounted display, subjects verbally described a memory, including that of a lost loved one, while in a virtual version of the home where the memory took place, with virtual heirlooms and virtual home movies as memory cues.

3. At the end of the sequence of conditions, a final memory test was used to assess the impact of the virtual memory environment. Participants were asked to remember the initial memory they first recounted in the audio recording, and afterwards, rate the vividness, clarity, and feeling of connection. The post-survey questionnaire was presented on a tablet after the virtual reality interaction.

In each condition, memories were cued by room-specific spatially anchored prompts (i.e., memories from the living room, the foyer, the den, the kitchen, etc., depending on the room chosen). Memories were prompted through collections of photographs that were taken in the original house, specifically, within accurate 3D scans of the room(s) that the subject discussed as their point of recall and remembering. There were no photos in the audio-based control, nor were there other memory cues present in the control.

6.6. Hypothesis

This study aimed to evaluate how the re-experience of simulated past places may enable a stronger autobiographical memory as a synthesis of common approaches common in reminiscence therapy. The overarching goal of the study was to examine the experience of teleabsence within a controlled environment.

We hypothesized that:

Figure 55: Demonstration image showing the researcher working with two subjects to set up the immersive mixed reality interface, viewing the memory boxes and the room surrounding them in mixed reality

1. H1: reflecting on a memory when alone, in the absence of others, would require individuals to rely on their imagination to generate memories, thus providing them with deep reflections on memories of the past, however, not evoking a strong sense of presence or a strong sense of co-presence with lost loved ones or lost environments;

2. H2: We believe that reflecting on memories in a virtual environment where the memories took place will foster richer, more detailed recollections, resulting in a more complete illusion of telepresence in the past, enabling individuals to feel copresent with lost loved ones or past places, more than just a verbal act of remembering in isolation,

3. H3: We believe that re-remembering the memories after remembering them in the virtual environment will cause the memories to be re-encoded, creating a new version of the memories that is more vivid, detailed, and visually vibrant, enhancing memory by reactivating it and using the virtual environment as a way to re-encode it.

4. H4: We believe that the entirety of a memory will be available across both conditions, but will vary in the degree to which it is accessed depending on the variables in each condition.

In summary, we hypothesized that:

- After experiencing a virtual environment from their past, subjects will report more vivid mental memories and a stronger sense of presence in the past, essentially re-experiencing long term memories in the present and re-encoding them into working memory,

Figure 56: Two of the participants shown interacting with the memory boxes, an image highlighting how the objects fostered closensess and togetherness

Figure 57: Overhead shot showing Charlotte interacting with the memory box

Figure 58: Documentation of interaction sequence by Charlotte, the most senior subject who preferred the tactility of the tangible object interface over the other scenarios

- The experience of re-visiting a simulated domestic environment from the past will enhance feelings of co-presence with lost or distant loved ones and memories, compared to experiences that rely solely on remembering verbally,

- This will have a positive effect on one's ability to remember vivid details of past memory, as well as potential effects on feelings of connectedness to loved ones.

6.7. Implementation

The duration of the experiment varied from subject to subject, but took approximately 45 minutes to one hour for each participant.

Video documentation of each participant and first person testimonial in the form of questionnaires and audio narrative recollection was recorded and preserved to analyze the emotional and affective difference between and across each of the conditions. Memories were initially reported orally, and recorded using a digital hand-held voice recorder.

6.8. User Interaction

In the present-day room, individuals saw specific elements of architecture, carpet, and furniture from the original space. In the experimental condition, each participant began the experiment by standing over the sofa in the living room of the re-installed house, after donning a head mounted display. Each participant then saw the room in the present day through mixed reality pass through.

In the first phase of the mixed reality scenario, participants were provided with a series of mixed reality photographs that co-existed in the present space of 215. These photographic prompts were curated from original photos from the original house, 220, depicting the space that each participant selected as specific to their memory when in the control condition. For example, if the participant had listed their memory as having taken place in the living room, they would see photos from across the years that showed different parts of the living room (see figure X for an example).

Each participant was then instructed to sit backwards once they began to hear music emanating from the head mounted display. Peggy Lee, a musician from the time period of the memories, would serenade the users with an emotion inducing rendition of House on the Hill. As the participants sat backwards- towards the sofa- the room in front of them faded, gradually becoming the original room from the house across the street. Once sitting down, the music filled their space, and the participant's focus became clear, viewing the environment around them as an augmented reality collage of memories past moments, in an overlay of the past room augmenting the present room.

In the immersive mixed reality interface, tangible elements of the room, such as core components like furniture and carpeting, remained unchanged, while a visual overlay of a virtual environment from the past was reprojected onto the space and mapped onto its geometry.

Participants did not move or exhibit locomotion during the study. Certain objects existed at the convergence of both the digital and physical, located under the user's static position on the sofa. These objects existed on a shared physical/digital coffee table that existed in both the present, real space and the virtual mixed reality spaces, simultaneously. This relationship between the real and the digital was specifically designed to enable individuals to be able to be both in the present and the past, with living people in the present, as well as in the virtual setting, with videos and memories embodying those they have lost.

Figure 59: Sequence of transition from present to past

Figure 60: Two of the participants shown interacting with the memory boxes, an image highlighting how the objects fostered closensess and togetherness

6.9. Measurements

The study results are composed of the following:

- **Quantitative data** from pre- and post-surveys, each related to a specific condition of the study. In particular, the following would validate our hypothesis: an increase in feelings of presence or an increase in the vividness of visual imagery.
- **Observational data** from participant behavior during the event, including participant affect, explicit behavior in the form of emotional expression, and participant reaction.
- **Qualitative data** from participants' self-reports, addressing their experience of memory, perspective on the memory, and other feedback on the experience of the simulation.

Subjects' experiences were evaluated to determine how imagining memories differed in each condition.

Firstly, we evaluated how the subjects' experience of memory impacted their feeling of presence in the virtual space. We assessed this using scales and self-report measures in the questionnaire section of this proposal, specifically employing the Vividness of Visual Imagery Questionnaire.

Secondly, we evaluated how the subjects described the vividness, visual imagery, and clarity of their re-remembered memories after each condition. We determined this by rating the vividness of each memory, comparing word counts across conditions for the descriptions of each memory, as well as evaluating the time spent in each condition.

6.10. Measurements and Results

We asked the participants to report on a Likert scale:

- The vividness of the memory
- Rating of connection to loved ones

We compared:

- Word count for descriptions of memory
- Comparing the number of episodic and semantic segments recalled

6.11. Assessing Participants' Sense of Presence and Engagement

To assess participants' sense of presence and engagement with their memories, participants were asked to rate the following statements on a scale of 1 to 7: (1) "Please rate your sense of being in the memory, on a scale of 1 to 7, where 7 represents your normal experience of being in a place." (2) "To what extent were there times during your act of recalling memory when the memory was 'reality' for you?" (3) "When you think back to the memory in your mind, do you think of the memory more as images that you saw, or more as somewhere that you visited?" (4) "During the time you were thinking of the memory, which was the strongest on the whole, your sense of being in your memory, being where you are, or of being elsewhere?" (5) "Consider

Figure 61: Screeenshot of the experimental condition partially faded into the room

your memory of being in the remembering the memory. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory', consider things like the extent to which you have a visual memory of the experience you remembered, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements." (6) "During the time of your experience, did you often think to yourself that you were actually in the memory?"

6.11.1. Assessing the Vividness of Mental Imagery

To assess the vividness of participants' mental imagery, participants were asked to form a mental picture of the people, objects, or setting for each of the following scenarios and rate the vividness of the image using a 5-point scale: (1) "No image at all, I only 'know' I am thinking of the object." (2) "Dim and vague image." (3) "Moderately realistic and vivid." (4) "Realistic and reasonably vivid." (5) "Perfectly realistic, as vivid as real seeing." Participants were instructed to use a rating of '5' only for images that are as lively and vivid as real seeing, and if they did not have a visual image, they were to rate the vividness as '1'.

6.11.2. Assessing the Vividness of Mental Imagery of a Relative or Friend

To assess the vividness of participants' mental imagery of a relative or friend from a recalled memory, participants were asked to consider carefully the picture that comes before their mind's eye and rate the vividness of the following aspects using a 5-point scale: (1) "The exact contours of face, head, shoulders, and body." (2) "Characteristic poses of head, attitudes of body etc." (3) "The precise carriage, length of step etc., in walking." (4) "The different colors worn in some familiar clothes." The rating scale is as follows: (1) "No image at all, you only 'know' that you are thinking of the person." (2) "Dim and vague; flat." (3) "Moderately clear and lively." (4) "Clear and lively." (5) "Perfectly clear and lively as real seeing."

6.11.3. Assessing the Vividness of Mental Imagery of a Specific Room

To assess the vividness of participants' mental imagery of a specific room from their memory of 220 Jefferson Drive, participants were asked to visualize the room and consider carefully the picture that comes before their mind's eye. They were then asked to rate the vividness of the following aspects using a 5-point scale: (1) "The time of day and the foyer when you arrived." (2) "The color of the walls and the time of the year." (3) "The objects in the room, the lighting, sound, and feeling." (4) "The feeling of being there together with your loved ones." The rating scale is as follows: (1) "No image at all, you only 'know' that you are thinking of the person." (2) "Dim and vague; flat." (3) "Moderately clear and lively." (4) "Clear and lively." (5) "Perfectly clear and lively as real seeing."

6.11.4. Assessing the Vividness of Mental Imagery of a Shop

To assess the vividness of participants' mental imagery of the front of a shop they often visit, participants were asked to consider the picture that comes before their mind's eye and rate the

Figure 62: Charlotte smiling at the vision of the past environment she enjoyed over 40 years ago

vividness of the following aspects using a 5-point scale: (1) "The overall appearance of the shop from the opposite side of the road." (2) "A window display including colors, shapes, and details of individual items for sale." (3) "You are near the entrance. The color, shape, and details of the door." (4) "You enter the shop and go to the counter. The counter assistant serves you. Money changes hands." The rating scale is as follows: (1) "No image at all, you only 'know' that you are thinking of the person." (2) "Dim and vague; flat." (3) "Moderately clear and lively." (4) "Clear and lively." (5) "Perfectly clear and lively as real seeing."

6.11.5. Assessing the Vividness of Mental Imagery of a Country Scene

To assess the vividness of participants' mental imagery of a country scene involving trees, mountains, and a lake, participants were asked to consider the picture that comes before their mind's eye and rate the vividness of the following aspects using a 5-point scale: (1) "The contours of the landscape." (2) "The color and shape of the lake." (3) "The color and shape of the trees." (4) "A strong wind blows on the trees and on the lake causing reflections in the water." The rating scale is as follows: (1) "No image at all, you only 'know' that you are thinking of the person." (2) "Dim and vague; flat." (3) "Moderately clear and lively." (4) "Clear and lively." (5) "Perfectly clear and lively as real seeing."

6.11.6. Assessing Participants' Beliefs about Life, Death, and Legacy

To assess participants' beliefs about life, death, and legacy, participants were asked to read each of the following statements and select how much they agree or disagree: (1) "My death does not end my personal existence." (2) "There is a Force or Power that controls and gives meaning to both life and death." (3) "I may die, but the streams and mountains remain." (4) "Meaningless work makes for a meaningless life." (5) "It is important for me to do something in life for which I will be remembered after I die." (6) "If others I love do not remember me after I die, my life will have been wasted." (7) "To be creative is to live forever." (8) "After death, much of myself lives on through my children." (9) "Relationships with family and friends are among the most lasting values."

6.11.7. Assessing Sensitivity to Surroundings and Experiences of Connection

To assess participants' sensitivity to their surroundings and their experiences of connection, participants were asked to select how much they agree or disagree with the following statements: (1) "Sometimes when I look at a person I feel a connection which is very special and different from usual human contact." (2) "I sometimes experience joy just from being in a beautiful place." (3) "I am very sensitive to the atmosphere of a house." (4) "I never feel that I am making contact with someone's soul." (5) "I can sometimes enter a state where I feel connected to the universe." (6) "For me, places do not have a special atmosphere." (7) "I sometimes experience other people 'shining with an inner light'." (8) "The physical world as we know it is all there is." (9) "I am not much affected by my surroundings." (10) "I never get completely immersed in the beauty of my surroundings." (11) "I can sometimes feel a connection with those who are no longer with us."

6.12. Participants

All subjects were mentally and physically healthy adults (between the ages of 50 and 95 years old). All subjects were preselected due to their familial bonds with each other. All subjects invited were pre-selected based on a network of biological relationships and social relationships. Each subject signed a consent form as a DocuSign link. All subjects had spent significant time in 220 Jefferson Drive, enough to have distinct memories of the space, the people who lived there, and each other. None of the participants had used virtual reality before.

6.13. User Study Results

We hypothesized that after experiencing a virtual environment from their past, subjects would report more vivid mental memories and a stronger sense of presence in the past, essentially re-experiencing long term memories in the present and re-encoding them into recent memory. We hypothesized that the experience of re-visiting a simulated domestic environment from the past would enhance feelings of co-presence with lost or distant loved ones and memories, compared to experiences that rely solely on remembering verbally. Finally, we hypothesized that this would have an effect on one's ability to remember vivid details of past memory, as well as potential effects on feelings of connectedness to loved ones, as well as anxiety about aging and loss, offering a refuge in time for individuals to reflect on.

By participating in the study, subjects had an opportunity to experience technology designed to facilitate visual representations of their past. This experience was designed to deepen personal connections with themselves, enabling them to be more in touch with places in their lives, and have greater perspective on who they and others are. As part of the study, they were enabled to

Figure 63: The surrounding social function was full of remembering, with many participants gathered closely discussing memories of their past together. It was noted by the host that “No one wanted to leave. I mean, they all stayed so long”

interact with places from their life in ways that could make them feel younger or in a different time in their lives.

Results showed that participants felt a greater sense of connection with oneself, and developed a greater perspective with which to reflect on their own experiences. ("It got me thinking about some of my feelings. They probably came out very truthfully but shocking to me.")

Interestingly, most of the subjects seemed to completely forget that they were on furniture from the original room at all, and did not pay close attention to the environment they were in. No subjects remarked that the temporary physical environment resembled the old home, failing to notice the sofa, chairs, or other pieces of furniture. As a result, we can infer that the architecture of the original space, paired with the appearance of the original members of the family by way of embedded media, was likely the strongest cues for feeling presence in the past place, as opposed to the physical artifacts in the present. Seeing the same furniture virtually reconstructed in the appropriate context did transport the viewers back to the past place.

Overall, older individuals had less clear memories and more general memories. Younger individuals had clear events to describe. Middle aged individuals tended to have specific spatially

Figure 64: Gaussian splat of the experimental condition, 215

organized memories. The exact details of the interactions and memories were not as important as the feeling of being there in some spatial relationship to the core people and places from the memory.

7. Chapter 7: Summary of Study Findings

> “It’s like being with everybody again.”

– Quote from participant in Jefferson Drive Simulation

After the simulation, the memories were in fact more detailed, with descriptions of individuals in them, showing that there was a positive impact on the imagination and memory recall as a result of the simulation experience. These results demonstrate that this research sheds light on the potential of virtual reality for research into the nature of the self, time, the experience of the past, and autobiographical memory.

Several participants expressed deep emotional responses and nostalgia when experiencing the spatial simulation environment. For example, Donna described the experience as “tearful” and “heartwarming,” feeling as though “time didn’t really happen”—referring to the duration of time from the past to the present—and indicating that there was an effect that the duration had in fact been eclipsed.

Overall, many of the memories did not seem to be about a particular experience, but moreover, a general ‘feeling’ associated with the events, which was found to be capable of being re-experienced in the present. Two of the participants, David and William, specifically reminisced about the joy and contentment they felt during the prior family gatherings, highlighting the special moments spent with loved ones, with David noting he felt “contentment at the end of a long Christmas Day” and William recalling seeing “a lot of Irwin and Mildred,” two of the deceased family members.

Josh detailed specific memories tied to locations and family members, mentioning “the dining room” and “the piano.” Marcie found the experience both beautiful and bittersweet, saying it was “almost eerie” and noting that it made her “really sad” to see that “it’s all gone now.” John had vivid, ‘continuous’ memories of the past, expressing a strong emotional connection to the environments and images and recalling how they reflected his sense of self, describing them as “vivid” and a “continuous timeline” that were “not just a part of me—they are me.”

Overall, the feedback indicated that the virtual environment in the experimental condition successfully evoked significant emotional responses and nostalgia, bringing past moments vividly back to life, more so than the control condition.

7.1. Sample Participant Evaluations

7.1.1. Marcie

Marcie remembered Christmas decorations and personalized gingerbread cookies at Aunt Millie and Uncle Ir’s house.

> "...it was decorated to the hilt, and they had food galore, for Christmas on the dining room table with all the silver platters and all the fancy um, ware and candlesticks.... and one great memory is my two- my daughter and... would pick out her- Mary Frances did a little gingerbread tree, and they’d all find their names on it, and it was just endless"

Figure 65: Marcie, a participant, shown enjoying the tangible elements of the experience inciting remembrance

> "It was weird seeing those pictures, kind of change your mind about some things"
>
> "It's amazing".
>
> "This is amazing"
>
> "Oh my God, this is almost eerie"
>
> "I don't know- that's weird I mean, it's a beautiful experience. I remember all of that. Like, vividly. It makes me really sad. It does make me sad. It's all gone now"

Control Condition: Marcie's account in the control condition (231 words) was detailed and descriptive. Marcie vividly recalled the dining room of the house and Christmas decorations, and the gingerbread tree with names. Marcie mentioned specific ornaments, her children's enjoyment, and the overall magical atmosphere created by Aunt Millie. Marcie highlighted the consistency of these memories over the years, specifically emphasizing the decorations and the joy they brought.

Experimental Condition: In the VR condition (209 words), Marcie's description was slightly more concise, but still rich in detail. During the VR experience, Marcie's narration was

Figure 66: David and Charlotte, David in VR and Charlotte using the tangible experience

emotional and reflective. She recounted the decorations and the gingerbread tree but added a layer of sadness about the loss of these traditions. Marcie focused again on the decorations, the gingerbread tree, and the family gathering. Marcie mentioned specific traditions such as her children finding their names on the gingerbread tree and the special dresses worn by her daughter and niece. The narrative maintained a similar tone and content, though it was more streamlined compared to Condition 1. The VR experience seemed to evoke a more personal and sentimental response, highlighting her deep connection to these memories.

7.1.2. David

Control Condition: David's first condition narrative (172 words) focused on the dining room during Christmas, specifically mentioning the gingerbread tree with names and the various foods available. He recalled the atmosphere, the food, and Aunt Millie's encouragement to 'eat more'. David's description was centered around the dining experience and the decorations.

Experimental Condition:

In the VR condition (241 words), David's account became more detailed and reflective. He described the atmosphere, the decorations, and his interactions with family members, particularly his mother and Uncle Ir. David's memory was quite similar, but included additional details about the chocolates and the gold coins for the kids. He repeated the memory of the gingerbread tree and Aunt Millie's hospitality. The overall content remained consistent, with slight variations in details. The VR experience brought out a sense of contentment and appreciation for family gatherings, with the virtual reality condition adding depth to his memories.

Figure 67: David exploring the tangible memory box

David recalled a Christmas memory in the den, sitting with his mother and Uncle Ir, appreciating the quiet and festive decorations.

> "The memory is being in the den, um, sitting in a very comfortable chair, uhhh, with my mom and my, um- Uncle Ir was there, kind of towards the end of the Christmas experience- and we were just sitting and chatting, and there would be different people coming into the room."

> "Um, and just- you know, the other memory of having mom there, and just the- just often, life was so busy, and just to have the privilege of just sitting in quiet with Uncle Ir and-and Mom, and having, and I almost felt selfish- this was time I-I can just have this presence with some of the people I love most in the whole world so that was- that was kind of a privileged memory, like feeling"

7.1.3. Harold

Harold recalled being sent to the basement during Christmas parties, playing pool with cousins, and memories of the train set under the Christmas tree.

> "All the kids were sent to the basement, and we would play pool, and all sorts of games with Michael Richard, and Brad Richard, and all the other cousins, we would

hang out there, but I also remember the dining room, where we would come in and eat dinner again."

Control Condition:

Harold's narrative in the audio recording (139 words) was focused on playing pool in the basement with his cousins. He provided a vivid description of the basement setup and the late-night activities. His memory was centered around the fun and games he shared with his cousins.

Experimental Condition:

In the virtual environment (137 words), Harold's description was consistent with the first condition, but included additional details about the dining room and the family picture in front of the Christmas tree. The main focus remains on the basement activities, but he added more context about the overall family gathering.

Figure 68: Deb, participant, shown looking to the left and right to view the other rooms in the house

7.1.4. Deb

Deb recounted a Christmas memory of being greeted by Brad and Irwin, and a humorous piece of advice from Irwin about keeping a napkin around a glass.

> "Irwin's advice. That day in the living room.. he handed us our cocktail and suggested that we always have a napkin around the glass, because that way, no one can keep track of the level of liquor in your glass, therefore affording you to easily refill it, without being chastised."

Figure 69: Jeff, participant in the VR condition, shown interacting with the mixed reality home movies

Control Condition:
Deb's first narrative (327 words) was rich and detailed. Deb described the Christmas celebrations, the meticulous decorations by Mildred, the mother of the family, and specific interactions such as Irwin's advice about cocktails. She highlighted personalized gifts and the warm hospitality of the Deans.
Experimental Condition:
In Condition 2 (205 words), Deb's description was more concise but more detailed. She repeated the story about Irwin's cocktail advice and Mildred's decorations. Deb's description maintained the essence of the memories, focusing on key elements like personalized gifts and the festive atmosphere.

7.1.5. Jeff

Jeff remembered Brad's 40th birthday party, a skit, and a humorous exchange about an absurd request for a trust distribution. Jeff's memory was among the most specifically detailed memories. Jeff's memory was more about the psychological nature of the individuals discussed than it was about the interior of the space. Several detailed descriptions in the VR condition differed from that of the audio condition:

> "It was Brad's 40th birthday. I think it was Mildred that came up with the idea of doing a skit to- you know, where…I, someone would-would play a Brad Dean role as a trust officer, and she enlisted me to be Brad.

Figure 70: Jeff, a participant, smiling in the mixed reality environment

> She wanted to… there was a, um, taxidermy elephant foot that she felt that ought to be in the in this space- in the new house, which it was an umbrella stand, and I can remember talking about that type of thing with her and it was- it was extremely enjoyable."

Jeff recalled the first and last names of several individuals present in the memory, as well as details of the time of day, conversations, and the overall dynamics of the evening.

Control Condition:

Jeff's narrative in the control condition (163 words) recalled Brad's 40th birthday party. He described the diverse group of attendees and a humorous skit performed during the party. The memory is specific and centers around the interactions and the event's atmosphere.

Experimental Condition: In the VR condition (481 words), Jeff provided a much more detailed account than in the control condition. He elaborated on the decorations, the interactions during the party, and specific objects in the house. He recounted the skit in greater detail and reflected on the convergence of Brad's different social circles. The narrative was richer and more expansive compared to the control condition.

7.1.6. Jamie

Jamie recounted a Christmas memory where she was greeted by her Aunt Milli and saw a Christmas tree with stockings and food.

> "I was standing in the foyer like, being greeted by Aunt Milli, and, at a Christmas party, with Harold and Donna and Mark, and I remember like looking into the

Figure 71: Jamie, a participant, with her daughter, exploring the virtual environment

> dining room and seeing like the Christmas tree set up with all the little stockings that everybody used to take, and the food on the table, lots of people there, like lots of like, laughter and talking, things like that."

7.1.7. Donna

Donna was moved by seeing objects and photos, recalling memories that made her emotional. Donna recognized environments and individuals, naming them and commenting on how they inspired more memories.

> "I remember every one of these. . . .Boy, these were great memories."
>
> "Great memories. I know what this is from. Must have been Irwin's one attempt at exercise that one day. The foyer was a very important part of that house. I loved it."

7.1.8. Mark

Mark recalled Christmas parties, the dining room, and personalized gingerbread cookies.

> "My memory of the dining room is mostly Christmas, and uh, the tree was there with all the little gingerbread people, and the individual name of all the kids, all the children had a gingerbread cookie."

Figure 72: Donna, a participant, in the virtual environment remembering the foyer of the home

7.1.9. William

William remembered Easter celebrations, with lots of Easter bunnies and a birthday party.

> "That's the dining room... let's see.... Easter.... Easter bunnies. Lots
>
> a Easter... bunny rabbits... must be Easter time.
>
> There's Mildred, there's Irwin. That's Irwin. He always had a joke...There's Mildred again, and Mary Fran. There's Mildred again. Mary Fran. That's Marcie- oh wow, that's Marcie and Jim Richard's. That's Irwin. There's Mildred. There's my mum, Annie. Looks like Eddie. That's Jonathan. That's the Christmas tree....where's the train set?
>
> "Um, I saw my wife and my brothers, and my mum. I saw a lot of Irwin and Mildred"

7.1.10. Josh

Josh recalled the annual Christmas party, playing pool in the basement, and conversations with Uncle Ir about Pitt football.

> "Oh there- oh wow....yeah, there's the steps going up. There's the dining room. There'd always be a nice spread for Christmas, and people hanging out in there, getting some food, going up the steps, I would always walk up there, put my coat in the coat room, come back down and go back down to the basement to play pool.....

Figure 73: Mark, participant in the study, in the virtual reality environment remembering gingerbread cookies

> "I always remember going in the basement playing pool- catching up with my cousin's, you know there was a Christmas tree. I always remember the Lionel train going around Christmas tree."
>
> "I don't know who that man is, but he looks fun to hang out with"

7.1.11. Judy

Judy recalled details from the annual Christmas party with gingerbread bears and other festive decorations, specifically locating that

> "The gingerbreads were on the Christmas tree that was in the corner."

7.1.12. John

John vividly remembers the den, where many gatherings took place, watching Johnny Carson with family.

Figure 74: Mark, participant, reviewing the tangible interfaces

> "Spent a lot of time in that den, whether it was a Friday night, Saturday night, during the week… spent a lot of time in that den- a lot of good memories- walk through the living room, didn't spend much time in the living room at all, but mostly the den, and that was- no matter what we did, we'd end up in the den."
>
> "Oh there's Jim. What happened? You guys look so young".

John remarked that nothing in the tangible object set sparked any memories, "I want you to know- I don't recognize any of this- in these boxes".

However, John did recognize the wallpaper and the fragments of carpeting.

> "— absolutely- Vivid… of all the time. like I said, in the recording earlier, 99% were all positive. Best times of my life"
>
> "You can never take too many home videos"
>
> He cried for over two entire minutes..
>
> "My memories are vivid…vivid" John repeatedly said.

Figure 75: Bill, in the virtual environment condition, was particularly adept at remembering names of individuals and the environment sparked vivid memories of his lost mother

"Yeah, all the time. There's not a week that goes by that I don't think about them. because, I mean, I spend so much time there… that those memories…. are not just a part of me- they are me. I mean- they are- they are me…they can't be separated. I mean, the only person that probably spent more time at 220 Jefferson Street- Drive- other than me, were Uncle Ir, Aunt Millie, Brad and Mary Fran. There was nobody who spent more time there than me"

'"But I will admit, that my positive memories stay longer than negative memories. I don't hold onto negative memories- at all. I don't have room. I've got- I've got to make room for the positive memories. I don't have any space, time- for negative memories".

"Oh yeah, but I was looking at others. I wasn't even looking for myself, because I was more interested in the memories of the others".

Figure 76: View of the interface from the overhead view of the participant, Bill

Figure 77: Josh, participant in the virtual environment condition, shown remembering the process of his movements through the house

7.1.13. Charlotte

Charlotte recounted her involvement in organizing events with Mildred and the liveliness of the Christmas parties.

> "I really don't know myself that well"

These summaries highlight the emotional and nostalgic reflections from each participant, emphasizing the strong familial bonds and memorable gatherings they experienced.

Figure 78: Judy, participant, shown remembering the location of specific treats throughout the original home

"and I knock, and tell them I'm here, and you're better be listening, he says, "I was not aware"… it's very personal and I always have one of my daughters with me because it's four levels up, and I have to stand on that chair and wake him up, so he hears it's my voice… it's, so- this tells you how you get wrapped up into how-how you react to certain situations. Now, I suddenly- I'm on that chair, and I see this little soul, she's coming around the corner- she's been there- and I come to life, and I see this body there, and I said, "Who invited you?". Oh, now I resented someone coming into my privacy- with my husband- because I'm communicating about the bills and all, and my kid is stunned, he says "Mother-" it's just… so, now the humor comes out of the situation. I was in that confessional, and the little lady spoke with an accent which shouldn't shock me and she says with the Italian background, "I come- I come here to look at my-my cousin he somewhere in a place here and I-I look for my cousin", I said "who invited you?"- and I suddenly realized, this is not a private place for you, Charlotte- this is to all those who lost their loved ones- suddenly you see, that-that is my spot, and I don't want anybody there when I'm there…."

"Same place. Felt like I was back at a party" "Yeah, it's like being back there"

7.2. High-Level Differences

7.2.1. Length and Detail

Narratives in the experimental condition were generally more concise than in the control, with a few exceptions such as the participant Jeff, who provided a much longer and more detailed

Figure 79: Documentation of participant, Judy

account in the experimental condition. However, all narratives in the experimental condition were more detailed, including more specific adjectives, examples, and often descriptions of key elements of the environments.

7.2.2. Focus

While the core content of memories remained consistent across conditions in keeping with the expectations of H5, the experimental condition often included additional details or slightly different focus areas, such as specific interactions or minor details of the setting. This can be attributed to the subjects' access to the original space of their memory in the simulation environment.

7.2.3. Emotional Tone

The immersive experience seemed to evoke a deeper emotional response, adding a layer of reflection and sentimentality not as prominent in the other conditions. This can likely also be attributed to the inclusion of emotional music used to incite stronger memory responses.

7.2.4. Repetition of Key Elements

Across all respondents, certain key elements such as specific decorations, family interactions, and personalized traditions were consistently mentioned. These details were critically related to the virtual environment used to cue the memory.

Figure 80: John, participant in the virtual reality environment, cried continuously for two minutes at the experience of immersive recall

This comparison highlights how the immersive environment influenced the structure and depth of personal narratives, with VR experiences bringing out more emotional and detailed recollections than the control condition of no VR.

7.3. Summary of Meaningful Content and Quotes from Interaction

7.3.1. Participants' Written Reflections

7.3.2. General Feedback

Overall, participants found the experience "interesting," "thoughtful," and "peaceful," appreciating the opportunity to revisit meaningful moments from their past. The use of virtual reality to recreate the Jefferson Drive home was valued for its ability to vividly bring back memories. The use of the super 8mm films in the virtual reality environment played a large role in creating an interesting experience for the users. This was the first time the participants had seen the home movies, as for over 40 years they had remained unopened in the basement of the house.

7.3.3. Nostalgic Reflections

Many participants expressed joy in reliving and reconnecting with their memories, often highlighting the virtual reality element as a unique and enjoyable aspect. Participants described the experience as "good," "fun," "wonderful," "pleasant," "peaceful," and "thought-provoking."

Figure 81: Charlotte, the most senior of the subjects in the experiment, recalled vivid and deep memories from her past, ultimately realizing she does not know herself as well as she thought

7.3.4. Emotional Responses

The experience prompted deep reflection and self-awareness, with one participant noting, "today was the first time I did a study on myself and how I really thought about some things."

Some participants, however, mentioned feeling "a little melancholy," indicating that while the memories were positive, they also evoked a sense of longing or bittersweet emotion.

7.3.5. Connection to Family

The experience was valued for its ability to connect generations and preserve family memories, with hopes expressed for future successes. Specific memories, such as Christmas past and seeing familiar faces, were particularly cherished. The experience encouraged participants to communicate more with others in their life, their family (or extended family), and reinforced familial connections.

> “It made us realize how intertwined our memories are” -MF

Most importantly, by reconstructing memories from their past, this study may help older adults (and the subjects in this study as they continue to age) construct biographical narratives and preserve them in a format that will later enable them to be re-experienced.

7.3.6. Key Quotes from written qualitative feedback after VR Condition

> "Wonderful experience, great memories that continue to form with each connected generation."

> "A wonderful walk down memory lane"

> "It got me thinking about some of my feelings. They probably came out very truthfully but shocking to me."

> "Very pleasant. I enjoyed the virtual reality of seeing the Dean's home. Very nice memories."

> "Interesting experience. It brought back fond memories. A little melancholy."

7.4. Social Experience of Memories

The experience of the virtual environment sparked reminiscence throughout the house and caused many conversations and interactions to occur about old memories. This was an unexpected and significant impact of the conditions, showing that sparking reminiscence in a social setting was particularly conducive to memory sharing and memory reinforcement.

The question emerges: Was having people imagine past experiences during the present potentially damaging to their experience of the present? Would they better experience their present, rather than imagine their past? Importantly, this study contributes to this question by showing that the integration of virtual past places into a present space can happen in a fashion that encourages present interaction by enabling past interaction.

Figure 82: The owner of the home and the oldest living subject

8. Chapter 8: Future Work

8.1. HCI Applications and Envisioned Scenarios

In this section, we describe a set of envisioned scenarios to provide a foundation for HCI researchers to further explore immersive nostalgia applications with virtual environment technologies for re-experiencing spatial memories.

We divide these potential applications into three areas: 1) wellbeing and healthcare for elderly individuals 2) applications towards telepresence systems and 3) interactive simulation interfaces. Finally, we discuss future applications using recent advances in wearable technology to develop spatially mapped three-dimensional lifelogs.

8.2. Wellbeing & Healthcare for Elderly Individuals

Long term implications of this research will enhance understanding of the potential of immersive virtual environments for generating, stimulating, and ultimately simulating remembering. Potential applications of this study will help us see if simulations of one's past enable individuals to store memories in virtual environments to later reaccess. Future systems could enable individuals to offload memories and create simulations where they could test, interact, and engage with past experiences that may no longer be accessible in long term care facilities. The impact of this research on telepresence as a remedy for loneliness, isolation, and memory regeneration may enable greater human flourishing, well being, and long term memory restoration.

8.3. Telepresence Systems

Future implementations of similar systems focusing on time-based 3D reconstruction could combine live feeds of users' homes with smart home technology to create a seamless link between virtual places and real, dynamic spaces. For example, having a live updated high resolution 3D reconstruction of your home as an application would allow you to share, in real time, a view of your home with another person. For example, one could guide another party through their home space if one party is absent and the other is there trying to locate an object. Furthermore, you could have social experiences in a real environment and later reshare them and re-experience them, storing interactions in the space where they happened. Finally, individuals can share experiences in personal virtual environments across long distances. Homes can be combined and real time physical spaces can be shared. For example, a table could have two shared spaces, both a virtual space and a physical space, and extend between two physically located tables.

8.4. Interactive Simulations

In the development of this project, we explored additional investigations that would enable the use of realistic 3D avatars of oneself in virtual environments from their past. One alternate approach used photo-realistic virtual characters to navigate spaces from a person's life, based on text narratives supplied by the user. A photo realistic three-dimensional scan of an individual could be prompted to create visualizations of memories that can then be modified and adjusted based on a users preferences. The hypothesis underlying this version of the project is that simulations based on oneself and workflows for personal virtual simulations will assist with memory recall, trauma processing, and self-conceptualization. Finally, training an agent on spaces from one's life may alternately create a different type of human-AI relationship, enabling us to have dynamic smart assistants that understand our physical spaces, intimate personal narratives, and can make suggestions, observations, and insights about our personal experiences.

8.5. Gaussian Splatting for Lifelogging

How do we see the past in the present? Using the Project Aria real-time egocentric camera system, a future project is focused on collecting egocentric data to better understand how users 'see' objects, people, and places that are no longer there. To explore this, I am utilizing Meta's Project Aria glasses alongside high-resolution virtual reality head mounted displays. In this pilot study, in the first condition, the subjects of the study will have their vision tracked in virtual reality while walking through the Jefferson Simukatton, the three-dimensional reconstruction of the house where they once lived. In the second condition, the subjects will visit the actual house - which has been sold, renovated, and changed by new owners- while wearing Aria headsets, prompted to remember their memories of the space as they navigate the space. Eye tracking and first-person egocentric capture of both the virtual and physical conditions will be documented and analyzed.

The goals of this research project are to explore how we can generate meaningful personal virtual experiences that simulate an individual's experience of their past. Can we determine from reconstructed eye movements paired with verbal description where something or someone was in space? How can we accurately map present day egocentric content onto reconstructions of past experiences to generate spatially persistent XR experiences, interweaving past and present states of places?

Other possible future iterations could explore placing first person egocentric gaussian splats in places where they were taken, so that by walking around, an individual could re-enter previous perceptions and experiences by activating the gaussian splat life-log. Adding audio memory overlays to photographs may also prove to be effective at creating a sense of active remembering in virtual interfaces that have embedded memories.

8.6. Ethical Considerations

In 1942, prolific author Jorge Luis Borges wrote of a man obsessed with remembering, who "Two or three times he had reconstructed a whole day; he never hesitated, but each reconstruction had required a whole day". The duration of this project ultimately overlapped with life so much as to eclipse it. Spending two years reconstructing the lives of someone else's prior fifty years had an effect on my experience of time and self. I felt what I had wanted others to re-feel, like I had lived through those experiences with someone else.

To what extent do we feel comfortable living in a virtual home? For many, it is imperative for users to feel that their personal location-based data is secure, and with this in mind, projects such as this must find methods for storing data locally to ensure that it is protected. Head mounted displays are by default socially connected technologies, which require the user to compromise certain degrees of control over their personal space.

Creating artificial variations of memories poses many potential risks. Environments from an individual's life could trigger traumatic memories, something we were very sensitive to at the outset of this investigation. Possible risks include confusion as to location in real time. There may be instances where the user fails to identify their present as real, and in fact believes the past to be real. Users could mis-identify the location of their memories, if they closely experience something in a false representation of place. This could ultimately result in a greater development of false memories in individuals.

In an in-store demo of Apple's Vision Pro in March of 2024, the end of the demo of spatial computing features a glimpse of the wild world, a stream beset in the mountains with an elephant grazing in the distance. Over this immersive, 360 image of the natural world, Apple's icon softly fades in, seeming almost like a trademark of the world itself. Seeing this can be stunning for many reasons—the image of the world, as a proxy, rendered in virtual spatial realism, is inherently visually captivating. Seeing the logo of a company, effectively interrupting and branding reality, is a different kind of unreal, a sort of a-ha moment that reminds you of the implicitly imperialistic agenda of contemporary technology. In 2025, Google unveiled a vision for the future of Google Earth, showing for the first time technology that can capture the interior of spaces and preserve them in an interactive public application. Current commercial efforts, such as WIST Labs and Varjo Teleport, feature innovative workflows for memory preservation that explore similar applications with contemporary computer vision methods. Each of these endeavors seek to control the distribution of real space into the virtual landscape. As this project probes the soon to be real reality of fully immersive memories of our personal realities, we must consider the potential implications of these records as they will become the property of others. How do we ensure the same degree of privacy old analog photos once enabled over the nature of our experience?

Figure 83: Found in the attic of the second home

9. Chapter 8: Conclusion and Reflections: Celebrate Everything

In "How to Live Forever," a New Yorker article from 2024 by author David Owen, Owen writes of a philosophy of longevity, one dependent not on science or technology, but in fact, simply the act and practice of remembering. Owen writes that "The simplest, most foolproof way to extend life is to do so backward, by adding years in reverse". Owen's philosophy describes how the act of archiving and storing the past can enable us to have an expanded experience of time and presence, effectively taking the duration of experience and through the cognitive act of remembering, expanding it.

What new ways are there of knowing people? Going through the things we leave behind is a place to start, by seeing who someone was to themselves. I remember when I first went into 215 Jefferson, the house that was emptied and used as a space to simulate the lost house. I was let in by the current owner. I remember finding in a closet upstairs where the daughter's belongings were kept. I sorted through a pile of her things, and what struck me the most was a book of Peanuts cartoons she had hand collaged together, taking strips of Peanuts from the Sunday newspaper and collaging them perfectly into a series of books. It reminded me of Sherry Turkle's memory closet. By looking through these hand collaged newspaper images, I felt close to the human being behind them.

9.1. Additional References

In "The End of Forgetting," writer Kate Eichorn explored the ethical implications of not forgetting. Eichorn points out how in the present day, the existence of digital archives prevents the past from being ephemeral, and as a result, may cause a deeper, prolonged experience of the presence of the past throughout our lives.

Albert Einstein wrote that "the distinction between past, present, and future is only a stubbornly persistent illusion." [CITE] "Here," a 2025 film by Robert Zemeckis, takes a unique approach to time and cinema, in that the film itself—about the subject of age and time itself—is filmed from a single perspective point, showing one location marked by the transformation and passage of time throughout history, and also through the story of a single family. One interaction of dialogue has a character played by Tom Hanks asking Robin Wright to stay over at his home: "You know, if you like, you could spend the rest of the night here," Hanks' character says, to which Wright responds, "I could spend the rest of my life here." The de-aging process in "Here" is accomplished through the AI-driven tool Metaphysic Live, applied according to director Zemeckis because "…the film simply wouldn't work without our actors seamlessly transforming into younger versions of themselves" "Here" presents an innovation in film-making that uses technology to show something deeply conceptual about the experience of human life.

9.2. Research Questions Conclusions

Our study aimed to evaluate how the re-experience of simulated past places may enable a greater sense of the felt experience of autobiographical memory compared to other approaches common in reminiscence therapy and verbal memory processing. We hypothesized that after experiencing a virtual environment from their past, subjects would report more vivid mental memories and a stronger sense of presence in the past, essentially re-experiencing long-term memories in the present and re-encoding them into recent memory. We hypothesized that the experience of re-visiting a simulated domestic environment from the past would enhance feelings of co-presence with lost or distant loved ones and memories, compared to experiences that rely solely on remembering verbally, or experiences that rely solely on artifacts and photographs for stimulating remembering. Finally, we hypothesized that this would have an effect on one's ability to remember vivid details of past memory, as well as feelings of connectedness to loved ones.

Questions we asked in this study include: What are the potential benefits and risks of experiencing virtual reality simulations based on your life experiences? Can immersive media improve memory? Does this impact one's feeling of age, sense of self, and experience of memory? Can re-encoding memories in virtual environments enable individuals to remember better? How can we create experiences that convey a sense of telepresence in the past, an experience of telepresence across time which may assist in mourning and grieving lost loved ones and lost places in one's life?

An ultimate goal of this project is to design a system that would construct a simulation of a space, such as the house one grew up in, from a text or verbal description in real-time. Ideally, this would result in a three-dimensional space that is a fair approximation of the viewer's memories. Future work then inquires as to how we could then dynamically simulate their memories through generative media based on personal data.

9.3. Final Reflections

In conclusion, these creative research projects discussed above adopt an interdisciplinary approach to investigate how we interact with virtual memories, focusing on understanding the psychological and cognitive parameters of the human experience in both virtual and real environments, and apply these insights to design novel simulation systems that can be embedded in the real world. By leveraging virtual environments that utilize ongoing advances in head-mounted displays, both augmented and virtual, as well as the integration of rapidly evolving artificial intelligence models, these projects seek to better understand how spatial interfaces and virtual experiences will impact and change our perception of our life narratives. This research endeavor aims to empower a range of people, including everyday users, XR designers and engineers, as well as social psychologists and cognitive scientists with a deeper understanding of the implications that arise from personal virtual simulations.

Objects and people represent our hopes and dreams. The very things life is made of. What does it mean to life when we can delete experiences? Social media and computing create an experience of reality that enables a digital philosophy of life itself. People can be deleted, past experiences hidden or altogether blocked. But we know the mind is not like this. Objects, people, and places not only linger, they are the true substance of life itself as it is lived.

The mind is a wonderful simulator, I can call up vivid perspectival apparitions of past people on the fly without closing my eyes. I see them nowhere in the world around me, but somehow they are there, between my seeing and thinking. Despite this, we don't remember well.

Towards the end of writing this thesis, I called my mom on the phone. We talked about the project, and she said personally wouldn't want to revisit places from her past if given the chance. I mentioned that the goal of the project was not necessarily to create media experiences for pleasure, but for when, if too old to remember, we could spark reminiscence for others like herself to help people regain a sense of who they were. In this conversation, she pointed out that pictures of our old house were still online. She sent me the link as I crossed over the bridge from the back bay to Boston. It was very emotional to me to see the pictures she sent, as I had not seen clear pictures of our old home since we left it in 2003. I took note of how this new phenomena of the permanent storage of images, 360 scans, and seemingly private data about our lives will become a future archive of place that will enable re-visitations like the one conducted here.

This research project introduces a novel method in lifelogging focused on the capture and representation of three-dimensional memory, utilizing contemporary advances in photogrammetry and three-dimensional image capture techniques. The experiments above explore how we can generate meaningful personal virtual experiences that simulate an individual's experience of their past as a way to develop memory aids for long-term memory recall. One of the goals of this study was to evaluate whether or not experiencing memories in virtual environments enables an individual to re-encode a memory from long-term memory, thereby potentially strengthening its ability to be recalled later or reassessed via memory cues stored in virtual environments.

The results of this study highlight the critical function of other people in forming memory and experience. Specifically as we age, memory is best constituted through interpersonal relationships, not simply self-reflection. Social bonds form the basis of remembering and memories. The most interesting subject in all of the footage and photography is always the photographer, the person who is outside the frame, because they are the lost subject to whom the captured subjects express their love. We, as the viewer, become this loved person when we view someone else's content. We see the smile of the beloved family and feel the mirth of the private moment we have been given privileged access to. In this way, the family photos of others make us- the observer- part of their family, reminding us of the deep truth of the human family we are all part of.

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10. Epilougue

11. In Memory of Elise

Figure 84: Elise

When the Tangible Media Group administrator, Elise O'Hara, passed away in December of 2023, I assembled a series of images of her from Hiroshi's iCloud account. By laying out the images in sequence, I started to see her again—I started to notice what in an image makes someone seem real, present and alive. It wasn't the images of her that she was 'posing' for, aware of being photographed, instead, it was the images where she looked startled, surprised, or caught off guard in a natural expression. These images brought her back to life for me.

Making the digital images into a physical book was an essential act to create a tangible way

Figure 85: Elise

to preserve what were otherwise only digital photo memorabilia. The day of the funeral, Jack Forman and I ran around the lab space trying to find the right kind of thread to use to bind the edges. We made three hole punches along the side of each page and then, in Jack's car, bound the books together on the way to the funeral. When we entered the funeral home, I was intimidated by the idea, but I walked up to Sean, Elise's husband, and handed him three copies of the book we had made. I made three copies because we knew that Elise's three children should each have one.

I remember that many lab mates at the funeral were surprised that we would have to see her again, there at the funeral. Because we had seen her so recently at the office, it was shocking to us that she would look the same way as when we last saw her, but not still be with us. There was the sense that she was in fact, asleep. It was very much like being with Elise, the sense that she was gone was hard for us to grasp.

We each mourned in our own way. To keep the memory of Elise with us, and to extend her presence into the lab, we created several memorials to her throughout the lab space:

Tahee, a visiting researcher from Hyundai, created a memorial of Elise's computer as a memory of her, by placing a printed out image of her on the back of where Elise's computer in

Figure 86: Elise

her office was, which you can see through the window. The resulting image created a vision of Elise in front of her former computer, so that when you pass by, you are reminded of where she once was.

I left photos of her in the placard outside the door of her office where her name was.

In the third floor atrium, we created a memorial where community members could leave photos, written notes, and memories of Elise. Dozens of notes and messages were taped to the wall.

On the LCD display, I ran a continuous loop of a candle every night for the week following her passing. I loved seeing the candle there at night, and when it was gone, it changed the ambience of the room. There was something really special about the candle filling the whole space of the lab with digital light.

In looking at the heartfelt messages about Elise in the open space on the third floor, it was clear how she touched many lives at the lab in a meaningful way. Some of the messages included:

> "Elise, your memory and spirit will forever exist, spreading joy and love with all the lives you touched and the kindness you brought."

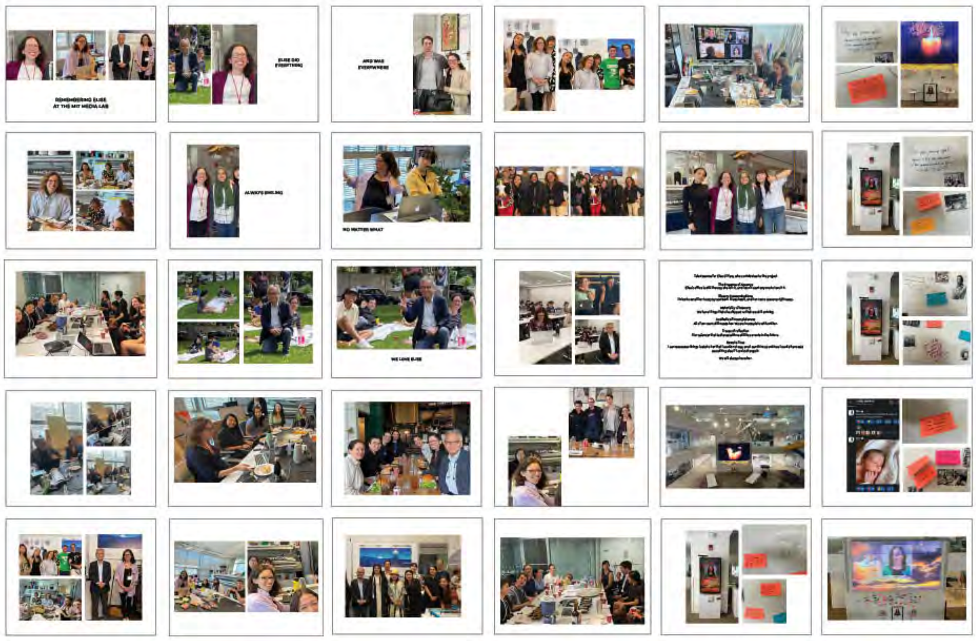

Figure 87: Elise

"Elise, you always rocked great shoes."

"Elise, you were tireless in your dedication to doing the right things."

"Your positive spirit, eagerness to help, and commitment to your community were a gift to us all."

"Elise, your remarkable dedication was the heartbeat of our group."

"We love you so, so much, we will miss you so deeply."

"Thank you so much for your service at the lab."

"You will be dearly missed. May your family find strength and resilience through these hard times."

"You will be missed. I'm glad to have known you. Thank you, Elise."

These messages, taken together, paint a picture of Elise as she was to those who knew and cherished her, a beloved and respected member of the MIT Media Lab whose kindness, dedication, and unique personality made a lasting impact on everyone who knew her.

At the memorial we held at the MIT Media Lab, which took the place in lieu of our traditional holiday party, Ishii could barely say much, and started to weep when at the podium.

In the first floor lounge, it was important to see Elise's presence hosted on an LCD screen, next to the three dimensional prints of other important MIT women, as an art installation that winter filled the first floor foyer with 3D sculptures of important MIT women PHDs.

It was only after Elise left us that I learned she was an actor, coincidentally from Emerson College in downtown Boston. I did not know that she pursued acting (while somehow also staging the theater of our lab), but one post online about her role in You Can't Take It With You told her story to me.

11.1. About Elise (Republished from the internet)

"If you have yet to see Roslindale actress Elise O'Hara in the Milton Players production of Little Shop of Horrors, you must get your tickets!!! O'Hara has been a member of the Milton Players for about a year after being cast in You Can't Take It With You and has quickly become an important part of the family! Now she is enjoying being able to play multiple roles as a member in the Little Shop ensemble.

When asked what audiences will appreciate about this production, O'Hara chuckles and replies, 'the small humorous moments tucked into and in between musical numbers.' In rehearsals, she has had a tremendous time discussing and developing backstories for the unique Skid Row characters with fellow ensemble member Kellyn Campbell. You'll crack up when you see what they've created! Get your tickets while they last!!! There is still one weekend left to catch Elise O'Hara!"

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Gordon Bell Takehiko Nagurama

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Dedicated to The Dean Family the Hall Family My family