Memory Tracer & Memory Compass: Investigating Personal Location Histories as a Design Material for Everyday Reminiscence

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ABSTRACT

With the massive adoption of smartphones, location trackers, and GPS-based applications, data is being generated that captures people's geographic locations in more precise detail than ever before. Personal location history archives offer a potentially valuable and overlooked resource for supporting reminiscence and recollection of the past. Yet, little design research has explored how location histories can be used as a material in designing such experiences. To investigate this space, we engaged in a practice-based design research process that resulted in two design artifacts. *Memory Tracer* is a tangible device that occasionally, yet perpetually surfaces locations from the past bound to today's date. *Memory Compass* is a smartwatch application that uses a 'casting' interaction enabling a user to retrieve and explore locations from their past, across space and time. We unpack and reflect on key decisions in our design process and conclude with opportunities for future HCI research and practice.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Interaction design process and methods.

KEYWORDS

Location history, Temporality, Design Research, Reminiscence

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1 INTRODUCTION

From displaying travel mementos to curating a map with pins, tracking the places that one goes is a common practice. The capture and recollection of locations visited across one's life can play important roles in supporting self-reflection, social connection, and the construction of memories [4, 5, 48]. The growing presence of technology in everyday life has greatly expanded the capacity to precisely capture, track, and reflectively consider places one has visited. The convergence of social, mobile, and cloud computing services and the increasing ubiquity of location acquisition technologies (e.g., GPS, GSM networks, etc.) [19] has created a world where digital devices and services generate logs that capture a person's location in highly precise ways [85, 129]. For example, as a by-product of people using services such as Google Maps Timeline [43], a standardized form of metadata is generated that contains exactly where someone is at any point in the day.

While nascent research has shown that location information can aid in the recollection of memories (e.g., [54, 71, 112]), the sheer size and scale of personal location history data that now exists presents new challenges for the HCI community. Location history data is largely invisible, often buried in software applications or across online servers and databases. This can cause losses in awareness over precisely what is contained in one's personal location data, as well as where it is stored [83]. Digital location history data often lacks a distinct material form and presence, which restricts people's ability to casually engage with it as an everyday resource for reflecting on life experiences [85]. Taken together, these issues make it difficult for people to get a "grasp" on what their location history data is, what is captured within it, and how it might be drawn on as a valuable resource for reminiscence.

The emergence and accumulation of large, continually growing personal location history archives creates new opportunities for people to reflect on the places they have traveled to and the role such places played in shaping who they are today. Yet, the use of location history data to support reflective experiences, like everyday reminiscence, is underexplored in design. In parallel, there are calls for more HCI research that investigates how alternative forms of personal data can aid people in exploring their life from different perspectives over time (e.g., [30, 51, 80, 105, 107]). However, examples illustrating how such engagements with personal location

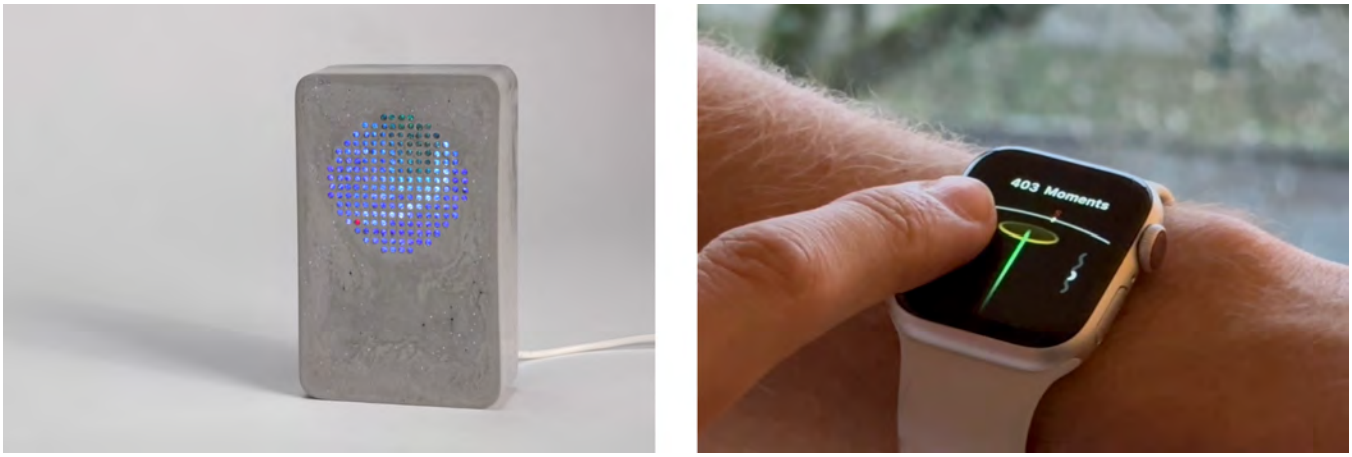

Figure 1: Memory Tracer *(left)* displays a low fidelity map of where the user was on this date in a prior year. Here, it shows Key West, Florida. Memory Compass *(right)* allows searching for past location moments in a given direction. The green line indicates the distance filter and changes as the user rotates their wrist; the yellow circle indicates the radius filter and changes as the digital crown is turned. Here 403 location moments are within the current filters.

history data can be mediated through the creation of new design artifacts remains sparse.

How will personal location history archives be meaningfully experienced as they continue to evolve and expand to scales that people have never previously experienced? How might inquisitive, reflective, and ongoing experiences be supported as they age over time? What opportunities are there to use this personal location history data as a resource for everyday reminiscence on the places and activities bound up in one's past?

Our approach to investigating these questions originates with and concerns practice-based design research in HCI [c.f., [2, 18, 39, 79, 79, 88, 96, 122, 123, 130]. We employ a designer-researcher position that emphasizes first-hand insights emerging through the creation of real things that materially ground conceptual ideas through their actual existence — "*a process of moving from the particular, general and universal to the ultimate particular – the specific design*" [74]. Our approach builds on and mobilizes a practice-led research that Archer, following Frayling [35], situates as "systemic enquiry conducted through the medium of practical action; calculated to devise or test new, or newly imported, information, ideas, forms or procedures and generate communicate knowledge" [1:11]. In this way, designer-researchers often function as a small team that is reflexively focused on the creative, experimental, and novel outcomes of the design process that are critically and reflectively arrived at through design practice. Thus, practice-based research can contribute insightful, first-hand, and reflexive views of the practice of making design artifacts in response to higher-level concepts and research questions, and in light of design materials, tools, methods, and competencies (c.f., [6]). In our research, we leveraged our own location history data as a design material. We wanted to explore how making location history data more materially present and more interactive might open new possibilities for reflection on and exploration of places visited in our past. We also wanted to inquire into the intersection of personal life history and personal location history as aspects of temporality raised by *slow technology* [47, 81] and how this design-theoretic framing might offer rich ways to support experiences with location data that change over time.

Our practice-based approach ultimately produced two design artifacts that reshape location history data into a material that can be tangibly experienced and lived-with (see Figure 1). *Memory Tracer* continually surfaces location moments from the past bound to today's date, showing them on a low-fi display within a cement enclosure. *Memory Compass* is a smartwatch application that allows filtering based on direction, distance, radius, and year to explore location moments based on where the user is. Through the design process of both products, we gained insights on how personal location history archives might be experienced as they continue to evolve and expand. Our research suggests that location data could offer a valuable resource for supporting everyday reminiscence that can scale over time. It is these insights, that emerged through the making of Memory Tracer and Memory Compass, that we reflect on in this paper. Next, we review related work; describe the journey of our design led research process; and distill implications for future HCI research and practice.

2 BACKGROUND AND RELATED WORK

Related work falls into three sections: reminiscence and location; digital records as design materials; and temporality.

2.1 Reminiscence, Location, and Technologies of Memory

Reminiscence is an informal, situated, everyday activity broadly described as "the recall of personally experienced episodes from one's past" [124]. While reminiscence in therapeutic settings is highly structured (e.g., [52]), in everyday contexts these experiences are often spontaneous, idiosyncratic, and open-ended. *Everyday reminiscence* has been characterized as unstructured autobiographic reflection that is often bound to a location (e.g., a childhood home) as well as life events that can be recurrent (e.g., anniversaries, reunions

with loved ones) or singularly unique (e.g., traveling to a foreign country for the first time) (c.f. [4, 10, 14, 48, 50, 56]).

The increasing prevalence of personal digital data, along with a growing interest in HCI toward designing for everyday life, has led to a stream of research exploring how reminiscence could be better supported. One key research area has focused on the creation of new technologies that enable people to attach digital content, such as images or audio recordings, to existing physical mementos (e.g., [37, 77]). Other research has investigated how the acts of capturing and exploring specific forms of media, such as images, video, and audio recordings, can effectively prompt reminiscence [58, 59, 73, 93–95, 108, 119]. There also exists a growing body of research that highlights the value of revisiting personal data, including social media, emails, online maps, chat logs, photos, and music to support reminiscence (e.g., [8, 29, 93, 94, 113, 116]). Peesapati et al. [91] exemplify this approach through *Pensive*, a system that effectively supported "individual, spontaneous reminiscence" through sending memory triggers, collected from social media data, back to end-users. Extending this work, Cosley and colleagues articulate key opportunities for supporting everyday reminiscence through leveraging data that is already captured by people and re-presenting this past information to them in new forms that can be experienced over time [20, 21].

In the context of location specifically, it is well known that location cues can trigger everyday experiences of recollecting memories [121] and reminiscing [92]. Recent research by van Gennip et al. [41] found references to location were among the most important prompts for reminiscence experiences. While there exists a range of HCI research investigating locative media and geolocative games (e.g., [7, 97]), only a handful of studies have explored how aggregated location data might support everyday reminiscence. *Rewind* [112] investigated how a person's location data can be used to reconstruct a first-person point of view video of their movement through space on a given day using photographic data provided via Google Street View. Findings indicated that re-presenting spatial pathways could be valuable in supporting recollection of memories, yet frictions emerged as the 'generalized' images taken from Google Street View could conflict with the interpretive experiential qualities of reminiscence. *Reveal* [71] is a smartphone application that leveraged geo-locative photo data on a user's iCloud account to resurface locationally relevant photos. This research showed that location histories can effectively support situated experiences of reminiscence, suggesting new opportunities to explore this promising yet underexplored design space. Finally, *Ritual Machine V* [11] explored how a parent's location data can be used when traveling away from home to map their 'place' onto an illustrated world that children at home can explore through a tangible near eye device. While not explicitly aimed at recollection of the past, this project does offer early evidence of how making location tangible, embodied, and embedded in everyday life can open opportunities for rich, ongoing interactions.

The works reviewed here highlight the HCI community's ongoing interest in developing novel ways to support people's experiences of reflecting on the past. Nascent works have begun to investigate new roles that personal location data could play in developing this research area, often through pairing it with visual media. These strands of research make clear that this emerging design space needs more research to better understand the potentials and limits for location history data to operate as a resource for reminiscence and reflection. We extend this research area through proposing and reflecting on two novel systems that concretely make location history data more embodied and embedded in everyday life.

2.2 Exploring Digital Records as Design Materials

As evidenced by the Quantified Self (QS) movement [100] in the last two decades, there has been a proliferation in the amount of precise personal data which can be and is recorded about one's day to day life [38, 68, 128]. The QS movement proports that the data intensive way of tracking many different aspects of one's life, behaviors, and activities can be helpful for the purposes of reflection, self-improvement, and self-knowledge. In parallel, there is ongoing interest in how personal data and metadata might be mobilized as a design material. Through the *Curatorial Agents* project, Gulotta et al. propose that metadata, related to time or location, can be considered highly important contextual factors *"that help situate digital information [for] evocative, meaningful, or relevant experiences"* [45]. This research, along with a trajectory of related work on digital possessions (e.g., [22, 32, 85, 102, 103]), opened opportunities for seeing data, like location histories, in a new way – not solely as a by-product of using systems that passively track one's life, but rather as a resource for supporting new ways of viewing one's past from alternative perspectives.

In advancing a generative critique of the QS movement, Elsden et al. argue there is a need for future research to investigate the design of interactions with personal data that expand beyond *"an exclusive interest in performance, efficiency, and rational [self] analysis"* [31]. The authors make a case for inquiring into how alternative representations of personal data can help people see their life from different perspectives and gain self-knowledge through this process. They argue interaction design must expand to creating personal data *"representations that support multiple perspectives rather than reductive explanations"* and which embrace *"the often complex and ambiguous relationships [we have] with our digital records"* [31]. Elsden and colleagues assert the place of personal data collected through passive tracking applications remains unclear and more research is needed to understand how such records can be transformed into design materials that reinforce human agency through new forms and interfaces [32].

Our work seeks to directly build on this prior research and contribute a practice-based design research process which investigated how location history data can operate as resources for supporting experiences of reminiscence through the places bound up in one's past. Our approach to designing interactions with personal location history data is highly influenced by research that characterizes data as a *design material* [12, 81, 82, 88]. We view working with digital data as a design material as analogous to how a carpenter uses wood as a material. Through use, carpenters become attuned to the physical qualities of wood, and they learn how to manipulate a piece of wood through various techniques of cutting, joinery, and sanding to craft it into something new. In the same way, designing with data as a *design material* seeks to use data as a resource for

creating new design artifacts. The aim is to understand the nuance and limitations of the data, the potential forms in which it could be expressed, and ultimately explore what can be created through using it. Beyond work that has come before, we investigate location history data as a material in-and-of-itself to better understand it in relation to design practice and how it can be given new forms and interactions.

2.3 Temporality and Design Research

Considering the scale and depth of different points in time that are captured in one's location history archive, our research is also influenced by prior works on designing for temporality and slowness. In their original works on *slow technology*, Hallnäs, Redström, and Mazé argue that design practice must expand to create "*technology that surrounds us and is a part of our activities over long periods of time*" [47] and inquire into "*what it means to design a relationship with a computational thing that will last and develop over time*" [69]. These works brought attention to the need to consider the generative qualities of temporality in design research. Extending this work, Vallgarda and colleagues [118] frame temporal interaction as aiming to "*slow down the expressions of computations enough to let us experience them.*" This statement is foundational to their argument that interaction design practice ought to be considered through a set of relations among physical form, interaction gestalt, and temporal form [117]. Pschetz and colleagues [9, 98, 99] highlight the need for research that explores temporal diversification through design and people's lived experiences of it. A handful of nascent design research projects have illustrated different ways slowness or temporally diverse interactions can be effective in supporting reflection on the past, most notably with photographs and music [17, 80, 81, 89, 114]. Yet, to date no known research has explored this framing in relation to personal location history.

The recent emergence of works in HCI related to slowness and temporality is valuable and encouraging. Researchers and designers have also expressed struggles in creating technologies that sustain longer-term experiences. Researchers have highlighted that early works advocating for designing for slowness are somewhat abstract and there is a need to further address how to design for slowness on conceptual and practical levels [53, 66, 86, 87]. In part aiming to address such concerns, Odom et al. [81] proposed a range of new design qualities that can be considered by designers when bridging the higher-level theoretical and conceptual aspirations of slow technology with design practice.

Our research aims to contribute to this research on slowness and temporality. We want to inquire into how digital history tied to locations can be explored as an aspect of temporality in slow technology. Through the detailed unpacking of two design research cases, our work concretely demonstrates and expands how the theoretical framing of slow technology can offer rich ways to support unstructured, curious, and embodied experiences of reminiscence with personal data that changes over time.

3 PRACTICE-BASED DESIGN RESEARCH: APPROACH, POSITIONING, AND RATIONALE

We adopt a practice-based designer-researcher approach to generate design artifacts that investigate and respond to our research questions (c.f., [6, 39]). This decision was motivated by several important reasons. While related work points to location history data's potential to offer a valuable resource for everyday reminiscence, no research to date has investigated it as a design material. Thus, we were motivated to adopt a practice-based design research because, as articulated by Archer, "there are circumstances where the best or only way to shed light on a proposition, a principle, a material, a process or a function is to attempt to construct something, or to enact something calculated to explore, embody or rest it" [1:11]. We needed to understand what location history data 'is' as a resource for design: how it can be shaped, worked with, and what its limits are. What we found – and unpack in the following section – is this process was a substantial undertaking. Our initial work made it clear that we needed to adopt an in-depth practice-based design inquiry to understand the qualities and nuances of location history data as they were progressively shaped into real and actual highly resolved design artifacts. Thus, our design-led approach enabled us to understand and leverage our own location history data through the iterative process of ideating and making various prototypes. We were able to rapidly test and understand how key design qualities of our prototypes offered promise to prompt everyday reminiscence. In light of this rationale, it was essential that we first engage in a design-led research approach to better understand the potential and limits of location history data as a design material for everyday reminiscence. Our position and commitment to offer a detailed reporting of the design journey of creating Memory Tracer and Memory Compass is inspired by and builds on the trajectory of work that is concerned with the development of new knowledge through the construction of design artifacts, and which views design practice in-and-of-itself as a form of inquiry, to critically investigate emerging issues in HCI (e.g., [3, 33, 34, 39, 40, 78, 110, 130]).

We designed Memory Tracer and Memory Compass to explore potential future interactions and experiences with location history data in everyday life and the role it might play in supporting reflection on places visited in one's past. Our design research process is highly influenced by conceptual propositions from the slow technology design philosophy [46, 47, 69] because we are interested in exploring personal life and personal location histories as aspects of temporality. Our design attitude is most specifically shape by the propositions that slow technology is a technology that *requires time to understand* and *changes through time* [47]. To investigate different parts of the design space and generatively inspire our process, we were also interested in mobilizing the somewhat oppositional design qualities of *implicit slowness* – a quality where the end user is able to freely control the design artifact while it still retains its 'slow' reflective character – and *explicit slowness* – a quality where the design artifact operates on its 'own time' and the pacing cannot be changed or modulated [81].

Over the course of two years, we reviewed theoretical literature, studies, and a range of design works. Similar to Schön's notion of design as a conversation with materials [104], we engaged in

a reflexive dialogue with our location data, design concepts, and physical materials to arrive at the designs for Memory Tracer and Memory Compass. The design research team consisted of four members with expertise in software development, interaction design, electronics prototyping, graphic design, industrial design, and digital fabrication. As a step toward acknowledging the subjective positions inherent to our approach, we include a brief description of our practical and disciplinary expertise in the service of increasing the transparency of our research inquiry. The authors of this paper are researchers that engage in research, design, and/or development across the following domains:

- Author 1 is an interaction designer and computer scientist with expertise in location-based services, iOS development, electronics prototyping, and industrial design;
- Author 2 is a HCI and design researcher with expertise in interaction design, slow technology, and theories of memory and reminiscence;
- Author 3 is an interaction designer and researcher with expertise in visual design, speculative design, theories of introspection and self-reflection, and practice-based research;
- Author 4 is an industrial designer and researcher with expertise at the intersection of digital fabrication and materials research.

This breadth of expertise enabled us to experiment with both digital prototypes and physical forms iteratively as a team. This paper was written over the course of ten months following our two-year design process, which involved numerous calls and meetings for retrospective discussion and analysis of insights from our design research. Across our process, we primarily leveraged the location history data of Author 1 who had been recording their location via Google Maps Timeline for the past 6 years.

There are limitations to this approach. It cannot be assumed that our initial experiences of reminiscence while designing and testing Memory Tracer and Memory Compass will be the same for others. Our experiences may be unique to our data, travel history, or the way we think about and remember places. However, by using our own data to design with, we were provided access to a dataset that would otherwise be very difficult to access. This decision enabled us to quickly and iteratively explore design qualities to see what sparked everyday reminiscence and what did not. Because so little prior work has been done in this area, we needed to first engage in a design process to generate multiple designs to better understand the nuances, qualities, potentials, and limits of location history data for everyday reminiscence. We documented our design process and annotated key design decisions relevant to our conceptual framing. It is important to note that as we iteratively prototyped, designed, and made Memory Tracer and Memory Compass, we needed to live with both designs (and various earlier prototypes) to gain insights which guided future design decisions.

While we include some first person experiences with the design artifacts as a part of our practice-based designer-researcher approach, it is important to acknowledge our research is not explicitly an autobiographical or otherwise empirical study (e.g., [23, 75]). Our approach to reporting and accounting of the design research process is more closely aligned with design journey narratives [25, 27, 55, 122]. With the design journey framework, the research team's design process is detailed through a post-mortem narrative that attends to specific design decisions that were shaped by key higher-level concepts. In the next section, we summarize our initial research working with location history data as a design material.

4 UNDERSTANDING LOCATION HISTORY AS A DESIGN MATERIAL: PRELIMINARY PHASE

We decided to focus on Google Maps Timeline as the service to collect and store location history for a few key reasons. While many apps (e.g., Strava, Nike Run Club, and Slopes [76, 106, 111]) track location during a specific activity, Google Maps Timeline constantly track's the user's phone, providing a continual record of locations. The service has been around since 2015 making it possible for us to engage with large archives of continuous location data. Google not only collects latitude, longitude, and timestamps, it also generates semantic location data by inferring activity and location place names. This decision came with some trade-offs. There is no available API for the data, and it requires a 3rd party corporation to store immense amounts of personal geographic whereabouts on their servers (clearly something with which people may be uncomfortable). Timeline data obviously will not contain 'all' locations a person has visited in their life, only the ones where the feature is enabled on an internet connected phone. However, of all currently available services, it is likely the most substantive data set of location history that any person has on themselves.

We primarily leveraged Author 1's Google Maps Timeline data. To aid our design discussions, we coined two terms to describe the data. The entire raw downloaded archive from Google consists of a JSON file with a single array of objects; we dubbed these objects "***moments***". Each *moment* always includes a timestamp, latitude, longitude, and accuracy value (see Figure 2). We dubbed a "***location day***" the list of all *moments* that took place on a given day (we *italicize* both terms throughout the paper to aid readability).


```
{
    "timestampMs" : "1492552922083",
    "latitudeE7" : 372242977,
    "longitudeE7" : -804198727,
    "accuracy" : 19,
    "activity" : [ {
      "timestampMs" : "1492552924862",
      "activity" : [ {
        "type" : "STILL",
        "confidence" : 100
        } ]
    } ]
}
```


Figure 2: An object from a Google Maps Timeline archive, which we termed a *moment*

The sheer amount of location data available made it challenging to work with at times. At the time of this writing, Author 1's location history contained over 70 months and over 130,000 *moments*. While we explored design ideas related to interaction and form

Figure 3: *Where Was I?* prototype *(left)* mapped a single *moment* from 'today's date in history.' *Sand Tracer* prototype *(center)* traced out a pattern representing a particular day's location data. *Photo Compass* prototype *(right)* allowed casting out in a certain direction and distance to return the nearest photo in your photo library to that point.

in parallel, an important early decision was to develop working software that could help us explore the potential of this data in a real and actual way. We began building crude prototypes and software scripts which helped us get a handle on what could be extracted from the data and the kinds of interactions and forms which might be possible. What follows are key insights we drew from the initial prototyping process, which further built the design space and ultimately shaped the form of Memory Tracer and Memory Compass.

4.1 Early Explorations with Location History Data that led to Memory Tracer and Memory Compass

The first phase of our design process was characterized by frenetically developing Python scripts and experiments to infer possible themes and insights. For example, by adding the total distance between coordinates on a given day, we could figure out which days we travelled for trips. These days and locations often were bound to numerous specific memories that were evoked without any other stimuli. Conversely, we were able to generate a list of the cities we most frequented. The results of this script did not spark specific memories but primed our recollection of many different memories across time and place. We ran the location data through different APIs to extract additional information such as weather, point of interest, and address. This script, coupled with inferred activity, provided an output something akin to: 'biking for 2 hours on a sunny Sunday afternoon in San Francisco.'

During this process, a key insight emerged from a Python script that mapped a random *moment* from the current calendar date but from a previous year (see Figure 3). We named this prototype *Where Was I?*. Through testing it on ourselves, we found that mapping a single *moment* from today's date in history could spark a memory. Clearly this approach has similarities to Timehop, Facebook Memories, Snapchat Memories, and Apple Photos' 'On This Day' which pair a 'day in history' with photos taken on that day. We found that not having a single photographic representation, but rather simply a locational point in one's past could trigger diverse and, at times, multiple memories to be recollected. In some instances, a randomly surfaced *moment* would spark a memory of a specific trip when it landed on an interstate roadway or one-off location. Other times it would spark a collection of memories when it landed at the location of a weekly activity. And many times, it landed in an area that we frequented almost daily, sparking memories, but often not related to the current date.

In parallel we began exploring how to tangibly represent location data. One prototype that sparked a lot of discussion within the design team was a prototype we named *Sand Tracer*, that could trace a pattern in sand (see Figure 3). The quality we liked most about it was the continual and slow reveal of an aesthetically pleasing pattern over time. We were intrigued by how this might represent a *moment* being surfaced from the archive.

An earlier script we designed returned *moments* near a particular location. After inputting a location, the script calculated and returned all *moments* in serial order of the distance away from that location. The ability to see *moments* regardless of date but in relation to a particular location primed our next design move. We prototyped an app that enabled us to 'cast' out a discrete distance in a certain direction. Wherever the cast 'landed', it returned the nearest photo to that point from the photo library (see Figure 3). This prototype prompted further ideas for a more embodied interaction that used a user's current spatial location and physical orientation as inputs to explore their location history.

Collectively, insights revealed by these early explorations encouraged us to use location history data as the sole data in our design inquiry and not merely treat location data as a "connective glue" for other kinds of data. In the next two sections, we describe and unpack how we moved from these initial design insights to the final form of both Memory Tracer and Memory Compass. For each design case we describe the design process and interweave retrospective reflections in dialogue with our higher-level conceptual framing. We then use a scenario to describe how each finished artifact operates. We conclude with reflections on our initial experiences with the design artifacts.

Figure 4: The interface progression of Sand Tracer *(left)* to Hourglass prototype *(center)* to Memory Tracer *(right)*

5 MEMORY TRACER

5.1 Memory Tracer: Design Research Case

Nascent research has shown that the slow technology quality of *pre-interaction* could be effective in shifting emphasis to *"designing for the time and space prior to the moment the artifact is directly interacted with"* [81] and, in this way, priming experiences for reflection with personal data. In designing Memory Tracer, we wanted to investigate if the pre-interaction design quality could be extended to prime everyday reminiscence through expressions of location history data that gradually change as *moments* are traced and eventually revealed.

Currently, location data lacks a distinct material form [83] which restricts people's ability to casually engage with it as an everyday resource for reflecting on life experiences [85]. This influenced our decision to make Memory Tracer a tangible device as opposed to a software application. A physical device might allow it to fade in and out of our awareness and would likely be able to provide different, more casual experiences of reminiscence.

5.1.1 Form Explorations. Following the Sand Tracer prototype, we initially envisioned the form for the Memory Tracer to trace *moments* in a miniature sandbox that were drawn daily and represented the total path that the user had taken on that 'day in history'. Although the traces could be tied to today's date and drawn to a relative scale, they remained unintelligible; there was not enough context to trigger experiences of reminiscence. We shifted to using a 16x16 LED matrix as the primary visual output for Memory Tracer. Because an LED matrix provided a higher resolution output, it had the potential to show more information about a specific *moment*. This made the device more understandable and more likely to spark reminiscence. We diverted from the explicit 'trace' of a path traveled and designed an animation akin to an hourglass, that progressively became more saturated until the display was entirely full, at which the *moment* is revealed.

Through living with the Hourglass prototype, we found a *moment* being surfaced in the background was delightful. Yet we found the overall experience underwhelming. The device was only showing a countdown to when a moment would be revealed in the future (see Figure 4). The temporal expression shown while a moment surfaced had been reduced to a form of clock time, that had no correlation with the location history data. The capacity to support pre-interaction and prime everyday reminiscence was lacking. After various experiments, we ultimately decided to make the focal point of Memory Tracer's interface a map of the *moment*. As the *moment* is surfaced, the display slowly shows more of the map. This gradually traced map, paired with slowly revealed contextual clues (that can be accessed if desired) provided enough context for Memory Tracer to remain intriguing, to trigger anticipation, and to support experiences of everyday reminiscence while the *moment* is being revealed.

In total we explored a variety of form alternatives (see Figure 5). Based on early experiences with the Sand Tracer and Hourglass prototypes, we arrived at the following requirements for the final form: 1) *Does not look like merely an enclosure for a screen* (in an effort to achieve a high quality of fit among other domestic objects

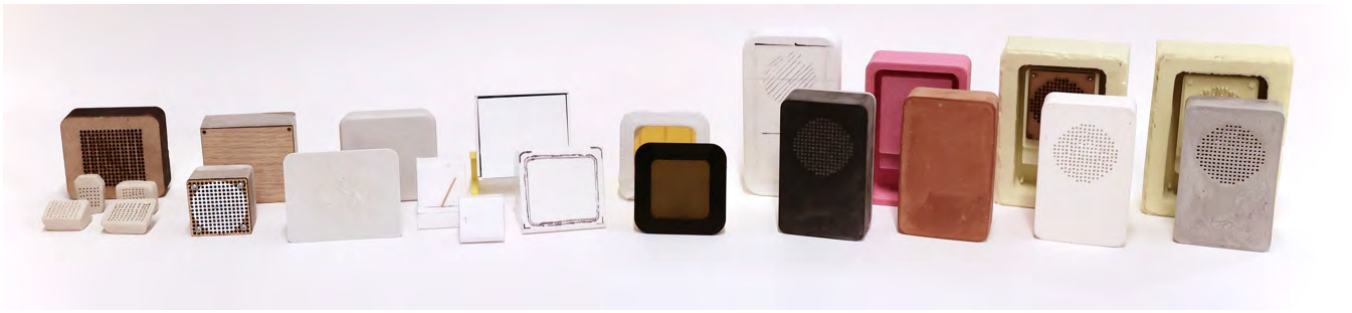

Figure 5: A progression of forms for Memory Tracer (chronologically from left to right)

and spaces over time); 2) *Invites peering into* (to support the looking at and pondering about what is being surfaced and equally enabling it to fade in and out of perceptual view in everyday life); 3) *Feels durable and weighty* (to evoke a physical sense of robustness and potential long lastingness).

Collectively, these requirements motivated our decision to cast the enclosure for Memory Tracer from Rockite, a water based rapid setting fine cement. This achieved our goal of a *durable and weighty* aesthetic. We adjusted the form of Memory Tracer to resemble a more rectangular monolith shape that was counter-weighted in its base and set the LED matrix display in the upper portion of the enclosure. This achieved our goal of it *not looking like merely an enclosure for a screen.* We also found that by cropped the corners of the matrix to create a more circular display it gave a more organic, unobtrusive aesthetic. It made the light look more like a portal that could be looked into, which achieved the quality of *inviting peering into.*

A challenge of using cement was that it does not allow light to pass through it. However, we discovered a way to route the light from the LEDs inside through fiber optic cable to the front of the enclosure. Beyond making it possible to only use cement for the form, this method helped create a quality of light that was vibrant and alluring, yet less intense and attention demanding. All the described changes in form enable Memory Tracer to fit in the backdrop of everyday life, support causal glances as *moments* are traced, and invite the user to more directly look into the device to consider places from one's past.

5.1.2 Working with Randomness and Aging in Location History to Explore Interconnections among the Past, Present, and Future. Our design led approach for making Memory Tracer was influenced by the related slow technology qualities of *explicit slowness* and *ongoingness* which, when combined, require the speed of the design artifact to not be controllable such that it expresses its *"own time"* [81]. Thus, the designing of Memory Tracer required attending to the connection between pacing and intelligibility. This came with the added challenge of designing a technique that would subtly grow and develop as location moments were surfaced, until they were revealed. Initially, we developed a random selection algorithm that was motivated by prior work demonstrating that randomness can help sustain ongoing cycles of everyday anticipation and retrospective reflection [65, 82, 89].

This led into explorations around pacing. We realized that if a new *moment* surfaced everyday this could be useful for getting accustomed to Memory Tracer when initially using it, but eventually this benefit wore off as Memory Tracer's behavior became too frequent and demanded too much attention. Conversely, a longer period of a *moment* surfacing every 10-25 days would lead to the device largely fading out of mind entirely. Both ends of this spectrum complicated our higher-level goal to create a slow technology that could move in and out of perceptual view and "become part of our lives over long periods of time" [47].

This prompted revisitation of slow technology theoretical propositions, which led to discussions of how the pacing of Memory Tracer itself could be used to provide added context for each *moment* and to support ongoing, subtle change through time. At this point, the *moments* Memory Tracer revealed were tied to 'today's date in history', but the amount of time they took to surface was entirely random. Critically reconsidering the way that Memory Tracer's pacing could express time, eventually motivated our decision to make the number of days that a *moment* requires before it is revealed to be equal to the number of years in the past of that *moment.* This idea was inspired from prior research that successfully used the pacing of a device to indicate the age of data that was being surfaced [60, 82].

The location history archive's age is always increasing as time passes, which causes the temporal spectrum for any *moment* to grow and expand and the pacing of the device to slow down over time. For example, if a person's location history archive is 7 years old, Memory Tracer will only forecast out *moments* a maximum of 7 days. Yet, as the archive grows older (e.g., 25 years) *moments* from deep in the past near the beginning of the archive would take nearly a month to surface, all while more recent *moments* would take only a few days to surface. This technique for structuring and expressing time highly resonated with us – practically, it meant that when one's location history was relatively young (e.g., 7 years) it would surface at a rate that would enable the user to have more chances to understand and become accustomed to it. As the user grows older and experiences accumulate with Memory Tracer, they could develop a sensibility for 'reading it' as the tracing periods become longer and more gradual when older *moments* are surfaced. This, in turn, could enable the longer periods of pacing to be less disruptive while building in subtle anticipation as the user reflectively considers *moments* from much deeper in their past. Yet, Memory Tracer would still retain the capacity to select, surface,

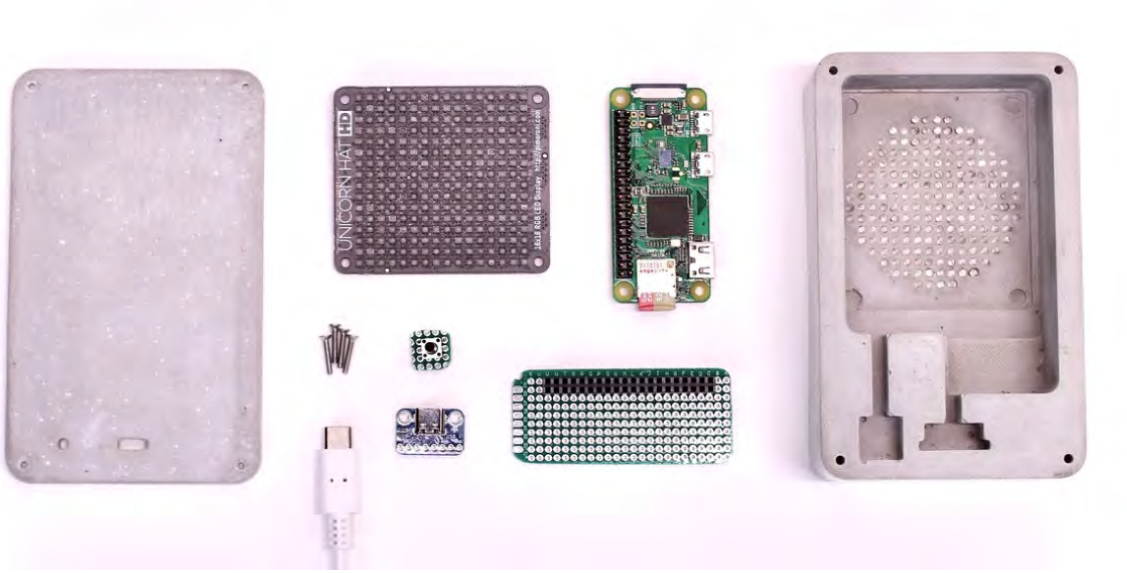

Figure 6: The main components of Memory Tracer: casted Rockite enclosure with embedded fiber optic cable, LED display, Raspberry Pi Zero, protoboard for connections, push button, USB-C breakout board, power supply, enclosure screws

and reveal *moments* that are more recent (e.g., from 1-2 years back), thus offering an unpredictable balance of showing younger and older *moments* and the different memories potentially tied to them. Ultimately, this design decision enabled us to manifest a sense of cumulative growth and aging over time that encompasses both the user and their location history. In effect, it brings together a near future date, that is connected to a time and place in one's past, that is experienced in the present through situated everyday encounters with Memory Tracer. This design leverages slowness and randomness to enable Memory Tracer to evoke its 'own time' while using the user's 'own' unique location history as the key factor of the pacing tempo.

5.1.3 Technical Implementation. The final version of Memory Tracer consists of the following elements (see Figure 6). We implemented a Python program on a Raspberry Pi Zero connected to an LED display embedded in Memory Tracer's enclosure. The program generates a database from the user's Google Maps Timeline location history archive and uses the timestamp metadata of each unique 'moment' as a key factor in its selection algorithm. As noted above, the device randomly selects *moments* from across the age of the archive. The database of location history data is stored locally on the Raspberry Pi. Memory Tracer's enclosure is cast from Rockite, which is a water based rapid setting fine cement. After casting the enclosure, we sanded it to a glossy finish using 2000 grit sandpaper. The display uses a Unicorn HAT HD, which is a 16x16 super bright multicolor LED matrix. Each pixel is connected to fiber optic cable, which is routed through the cement to ensure optimal light diffusion on the front of the device.

5.2 Memory Tracer: Scenario

When Memory Tracer is turned on, it connects to the user's location history archive and randomly selects a number that is between 1 and the total age of the archive. For example, if a user's location history archive spans 10 years, Memory Tracer will randomly choose a number between 1-10. As the archive ages, this time span slowly widens (e.g., next year when the archive is 11 years old, the random selection will be between 1-11, and so on). A cornerstone of the design is this random number is used for two things: forecasting how many days into the future until new *moments* will arrive and selecting how many years from the past those *moments* will be.

Consider the scenario visualized in Figure 7 and demonstrated in one of the supplementary videos to this paper. Here, the current date is June 14, 2022, and Memory Tracer's random algorithm *selects* a "7" from a 10-year-old archive. Memory Tracer then forecasts out, from the present, 7 days in the future to June 21st and selects a *location day* 7 years in the past (on June 21, 2015, in this case).[1] The system finds that 7 years ago on June 21st the user was in Key West, Florida, USA. Memory Tracer will then begin slowly *tracing* the *location day* by gradually producing a map of Key West on its 16x16 pixel display. The map will come into view pixel by pixel over the course of the next 7 days until June 21$^{st.}$ when the *moments* are fully *revealed*. During this tracing process, the user can press a button on the back of Memory Tracer to toggle through additional hints about the *location day*: 1) distance away from current location, 2) total distance traveled, 3) altitude, 4) temperature, 5) activity, 6) year, 7) city name, 8) point of interest. As the *reveal* date nears, more of this information is available.

In this scenario, on June 18th approximately half of the map will be visible, and half the hints will be available. Likely the location will not yet be intelligible to the user (see Figure 8). On June 21st the final form of the *moments* is *revealed*: a completed map view and access to all hints. The precise *moment* is shown with a red dot

[1] If there is no location data that corresponds with the random number, the random selection will repeat until a *location day* is found.

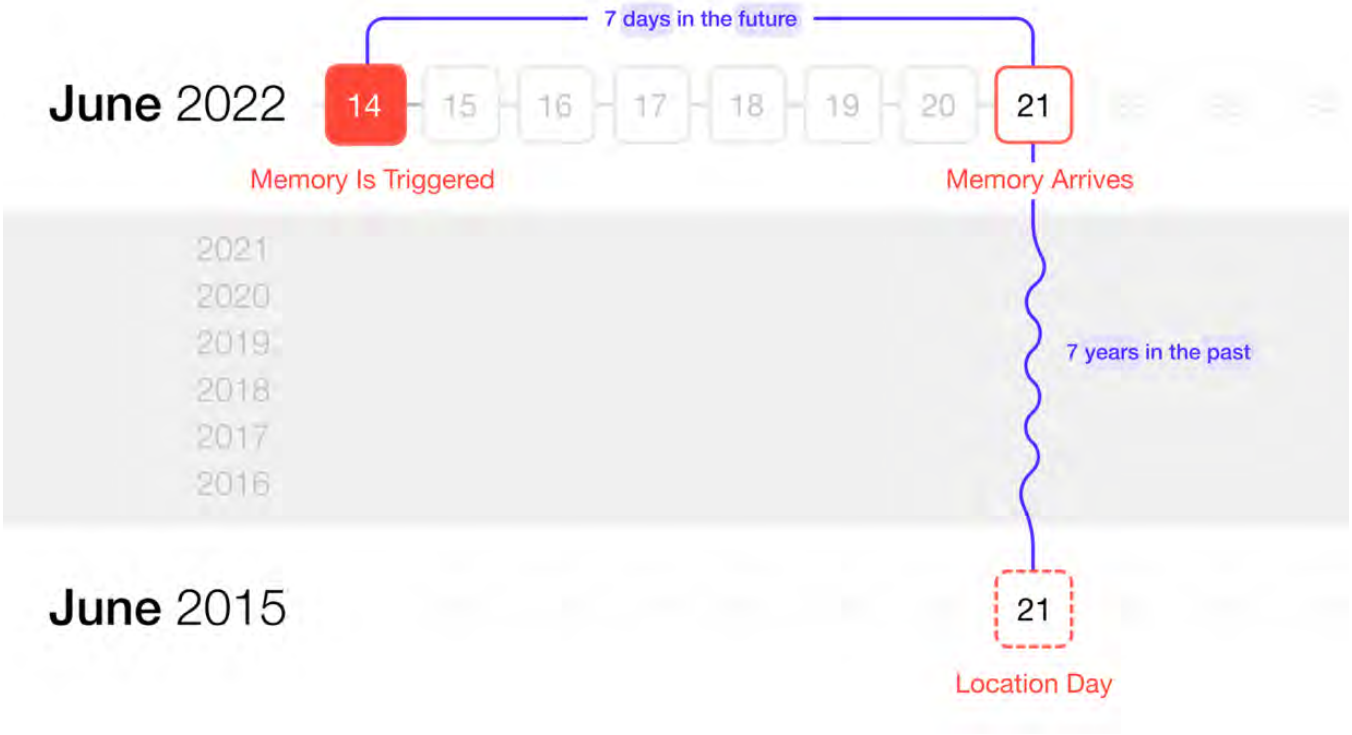

Figure 7: In this scenario, we have a 10-year archive, and 7 was randomly selected. Today is June 14, 2022. The algorithm will forecast 7 days into the future to June 21, 2022. It then looks 7 years in the past to June 21, 2015.

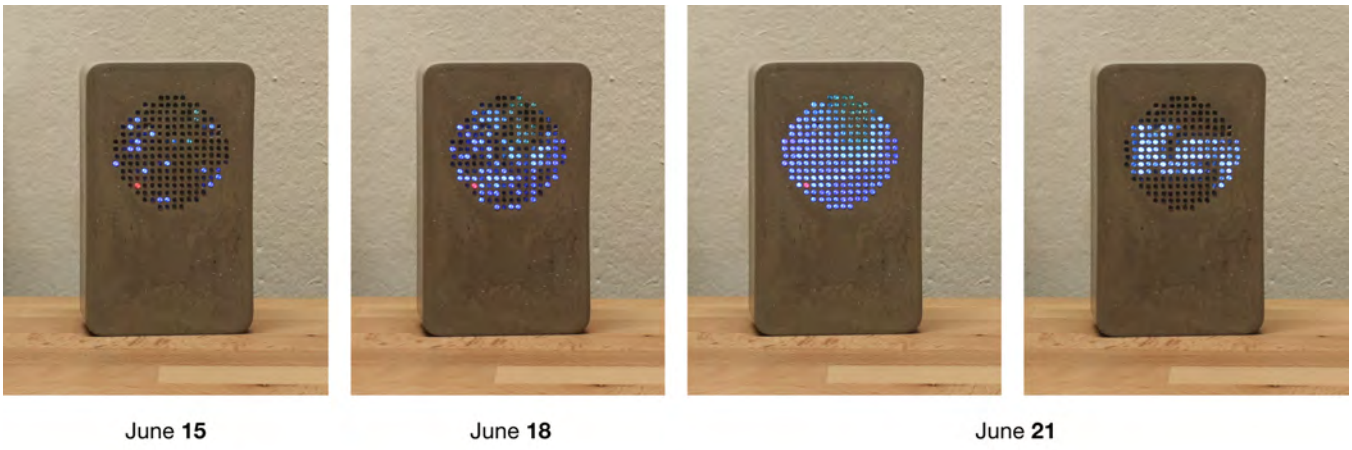

Figure 8: As Memory Tracer surfaces a *location day*, the map visual slowly comes into view. On the day the *moments* are from, the full map is shown, and all hints are available. Hints are shown by pressing a button on the back, which cycles through them.

and continually updates throughout the day. Access to the *location day* remains present for the full day (i.e., 24 hours). Then, Memory Tracer conducts the next *selection*, setting the date and location for the next reveal, which will begin to *surface* on June 22, 2022. This process continues indefinitely. The user has no control over when or what *moment's* will be *traced*.

5.3 Memory Tracer: Critical Reflection

Across making Memory Tracer and living with its final form, we found it was consistently able to present an inviting but subtle lived-with quality. Equally, we found it capable of supporting a range of experiences—from deeply reflecting on its presence, to glancing at

it via a fleeting reflection or, momentarily, to forget about it entirely. The tracing tempo frequently prompted prospective reflections on what *date in the future* the *location day* would arrive and from what *year in the past* a memory might be triggered. As tracing progressed, this could lead to a satisfying confirmation that the place we speculated was the *location day* being surfaced. Or this could lead to a change in perspective entirely if the map-based representation remained difficult to interpret (e.g., a heavy amount of blue was projected on the map, but we had no recollection of being close to large bodies of water).

Experiences with Memory Tracer also provoked us to think about time and our past in a unique way. Looking at Memory Tracer causes a dual consideration of how *far in the future* the date is and how *far in the past* the year is. This felt like a distinctly different approach to priming reminiscence and recollection. It often caused a higher-level reflection on what activities we were doing during a period of time (i.e., 1 week, 1 month, 1 season) that cut across the years of data. As Memory Tracer revealed more context, often this manifesting *location day* served as a narrowing of mental guiderails on what we likely should consider as the place in our past it is originating. Occasionally, the revealed *location day* would leave us with a perplexed feeling when we could not recollect the location or were not sure why we were there on this particular 'day in history.' In several instances this prompted us to look back through old calendars and photos, to try to remember why exactly we were there. Yet other times, *moments* were revealed that tied to a particular location or travels that had unique and specific memories attached for example: a road trip with a sibling, the apartment of an old friend, a visit to a famous landmark, or a meal at a memorable restaurant.

6 MEMORY COMPASS

6.1 Memory Compass: Design Research Case

In contrast to *explicit slowness* shaping our creation of Memory Tracer, our process for designing Memory Compass was influenced by the quality of *implicit slowness*. The pacing of the artifact is not enforced and can be freely controlled, but when combined with other design qualities, it retains its slow, reflective qualities [81].

6.1.1 Form Explorations. Following our initial *Photo Compass* prototype, we took inspiration from related design research that productively balanced user control with relatively minimal feedback to craft technologies that required time to understand, where a sensibility for 'reading' and exploring the system gradually developed through use and reflection [15, 57, 62, 80]. We considered different forms for Memory Compass, which ranged from handheld compass-like forms to bespoke near-eye devices that could guide one's gaze as potential *moments* were viewed. While we appreciated the potential of a unique tangible device, we realized this could make it become either tied to the home or stored elsewhere, limiting the kinds of experiences we hoped to evoke.

Ultimately, this led to using a smartwatch, specifically the Apple Watch. It already fits within people's lives, and the wearable nature means it will travel in, around, and outside of the home. We anticipated that these qualities could be important for supporting unstructured, spontaneous experiences of everyday reminiscence. We liked being able to quickly explore our location archive in relation to where we currently were in our everyday life. On a technical level, the Apple Watch's integrated combination of a gyroscope, compass, haptics, and connection to a smartphone made it possible to prototype different interaction design alternatives through several iterative cycles of use and reflection among the design team. Together, these qualities offered potential to support the higher-level goal of creating an *implicitly slow* design artifact: one which offers control but requires time to develop a sensibility on how it works that can scale and change over time.

6.1.2 Interaction Explorations. Initially, we envisioned an almost exclusively non-visual user interface for Memory Compass. We wanted to foreground attention and interpretation to the embodied act of retrieving (or 'casting') out into the world along a geographic trajectory. Our hope was that these embodied interactions could prime a space for pause, reflection, and, potentially, reminiscence on the *moment* that might be retrieved. In the first major iteration of Memory Compass, we experimented with approaches to physically retrieving *moments* through metaphors of scanning (moving arm left to right to left), throwing (similar to casting a fishing pole), and flicking (a quick swipe up on the screen) (see Figure 9). While the underlying system could be highly precise in translating a physical movement, it was challenging to understand how we arrived at the *moment* that was shown. Put simply, although the system was not random, it felt random because it was so challenging to 'learn' how the casting interaction worked. The feedback was so minimal, imprecise, and unintelligible that it complicated the higher-level goals of supporting longer-term experiences of everyday reminiscence.

After realizing the shortcomings of physically casting, we pivoted to a visual interface for setting *distance* and *direction* (see Figure 10). This iteration was certainly easier to use and afforded more understanding of where a cast may land, as one could see the actual miles it would cast out. While this did open some experiences of pre-interaction contemplation – *"What moments might be 300 miles away in this direction?"* – it did not provide the curious experiences we had set out to create; overall it felt too precise and quantitative. Another challenge was that so far, none of our designs provided a way to know if a cast would land near any *moments* at all, prior to casting. This lack of feedback required the user to cast and re-cast repeatedly to attune themselves to what was around them. While this fit with the goal of creating an *implicitly slow* experience, it also made Memory Compass frustrating to use.

Eventually, we arrived at a design that provided a representation of where a cast would land that visualized precise values for *direction*, *distance*, *radius*, and *year* in an abstracted way. We found that we could mediate the tension of not knowing where exactly a cast would land by displaying how many *moments* were within the cast's filters (see Figure 11). We found this iteration could support experiences of pre-interaction contemplation such as – "*Why are there so many moments right here? What could this area be?*" – "*Oh, I really thought that there would be some moments around here.*"

We refined Memory Compass so each filter has a unique embodied interaction along with visual and haptic feedback (see Figure 12). The ***direction*** filter is set by pivoting left and right, similar to how one would use a real compass. The digital compass in the smartwatch provides the precise direction. As the user turns, they

Figure 9: Three of the embodied interactions that we explored. While we particularly liked the idea of a throwing motion similar to fishing, it was too difficult to understand and left a feeling of total randomness in the interaction.

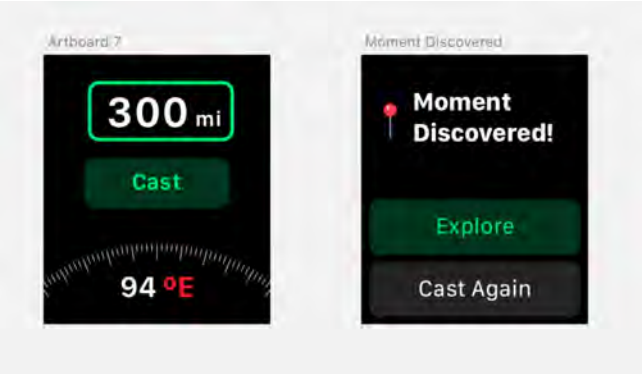

Figure 10: This version of the interface allowed precisely fine-tuning the values of *distance* and *direction*.

can feel haptic ticks for each degree. The ***distance*** filter is set by rotating their wrist outward to increase or rotating their wrist inward to decrease. The precise value is provided by the watch's gyroscope. Visually a line extends to indicate the increase of distance. Haptic pulses are also given to indicate the change. The ***radius*** filter is set by turning the digital crown outward to increase or inward to decrease. Visually the yellow circle adjusts in size, and the length of time between haptic pulses increases as the radius does. The ***year*** filter is adjusted through a long press on the screen. As the user presses the screen a continuous haptic pattern will start. Initially the intensity of the haptic pulse will be quite high, indicating a recent year. But the longer the press, the fainter the pulse will become, indicating a year deeper back in time. Eventually the pulse will stop, meaning that *All Years* are selected. All 4 filters are used together and can be adjusted in any order. As filters are changed, the current number of *moments* within the filter "net" is shown.

We were purposeful in designing a level of ambiguity into the experience. We do not show the precise direction, distance, radius, or year. At a computational level each of these filters has a precise value pulled from the compass, gyroscope, digital crown, and length of press. These values are used to calculate and find *moments*. However, the user only sees and feels an abstracted form of these precise values through the onscreen UI and the haptic feedback.

6.2 Memory Compass: Scenario

Consider the scenario visualized in Figure 13 and demonstrated in one of the supplementary videos to this paper. The user has input their desired filters and 'casts' by taping the screen. Upon casting, a map is shown of where the cast landed. The direction the cast came from is indicated by the green line (in this case it came from north of San Francisco). The size of the cast (radius) is shown by the yellow circle. If there are *moments* within the radius, Memory Compass randomly selects one and represents it with a pin. The user can Recast or View the *moment*. Upon viewing the *moment*, they will see a close-up map along with the date, time, location name (if available), city, activity (if available), weather, and altitude. The user is free to reflectively consider when and where in their past this moment ties back to, adjust the filters and recast, or simply go about their day after a brief moment of reminiscence.

6.3 Memory Compass: Critical Reflection

From a high level, Memory Compass' design qualities physically situated us within our location history data and provided a casual method of curiously exploring our past based on our current location. Over time it became clear that Memory Compass could support a wide range of experiences, from casting and pulling *moments* more locally to where we currently live, to supporting long distance casts that pulled back from various places around the world. Across different uses, the experience with Memory Compass and the types of memories it might spark were deeply shaped by where we geographically were when we used it.

When casting a short range around where we have recently lived, we found Memory Compass could return *moments* that are bound up within a recent time period. However, when Author 1 temporarily relocated to their family childhood home, *moments* were easily pulled back from much deeper in time. Perhaps unsurprisingly, when occupying a location never visited before, short casts were not as intriguing since the only *moments* that could be pulled back had just occurred.

Medium casts (10-100 miles) could offer mixed results, sometimes landing near forgotten *moments*, other times near frequented places. We found medium casts were productive in exploring around a place we had lived for several years. The medium distance is quasi-familiar – it is 'relatively close,' but it also emerged as a range where one does not visit every day, week, or even month. We found

Figure 11: The final version of Memory Compass used abstracted visuals to represent precise underlying filter values. The number of *moments,* displayed at the top, helped attune the user to where they were exploring before casting, giving rise to experiences of pre-interaction.

Figure 12: The interactions to adjust the *direction, distance, radius,* and *year* filters for Memory Compass

the radius filter could act as a way to increase the randomness or conversely let us pinpoint a particular part of the area.

Long range (100-1000 miles) nearly always generated a sense of curiosity around what might come back. At first, they were challenging to grasp and required us to adjust the filters to find any *moments* at all. The ability to see a continually updated number of *moments* within the current filters was particularly helpful at this range. Landing on faraway *moments* brought back a spectrum of memories we often had not consider or recollected on in several years. Slowly adjusting the radius smaller and smaller was particularly helpful at this range to 'hone-in-on' more specific areas of the world we had visited.

Yet, our cultivated sensibility had its limits. Super long casts (1000+ miles) remained hard to control as a couple degree direction shift would change the *cast point* by hundreds of miles. Nonetheless, this unpredictability added an intriguing quality – whichever *moment* was retrieved remained a unique result from the combination of embodied actions in the present with Memory Compass and unique location history data bound up in 'some part' of the world. Over time, we began to reflectively consider the relative *direction*, *distance*, *radius*, and *year* that we would be applied to a cast, before we would cast, and thought more deeply about the memories that might be returned.

7 DISCUSSION AND DESIGN OPPORTUNITIES

Developing approaches to enable location history data to better operate as a rich resource for supporting experiences of everyday reminiscence, recollection, and reflection over time, presents important opportunities for the HCI community. Through accounting and critically reflecting on our practice-based design research process

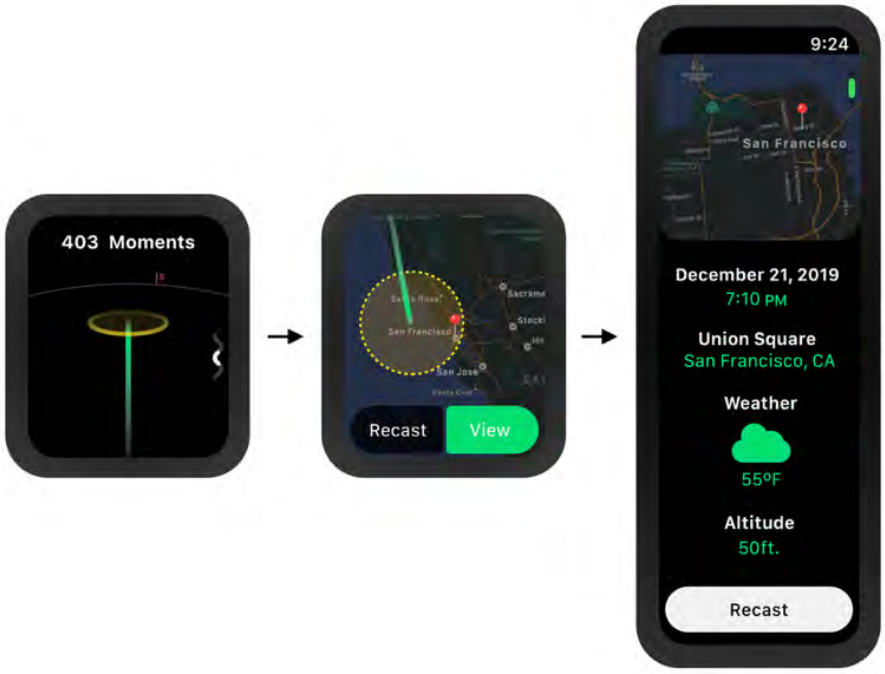

Figure 13: Once the filters are adjusted and the cast is 'launched', Memory Compass will show a map of where it landed, the radius size, and a pin if it found a *moment* in this area. The user can Recast or View the *moment*. *Moment* details show a closer map, date, time, location name, city, activity (if available), weather, and altitude.

for Memory Tracer and Memory Compass, we highlight opportunities and challenges that come with this emerging space and insights into how they could be better grappled with in future research and practice.

7.1 Leveraging Pre-Interaction and Anticipatory Interaction to Prime Different Forms of Memory-Oriented Experiences with Location History

Investigations into the experience of anticipation with interactive systems is an ongoing area of HCI research. Here, anticipation is commonly characterized as unfolding in two stages. First is a phase where experiences accumulate; intrigue, contemplation, and tension build over time. The second phase is when tension is released, and one interprets the content that is revealed (e.g., see [70]). Designing for anticipation is important for slow technology design artifacts because it can lead to sustained interactions that may strengthen attachment and enable them to become embedded within people's lives over time – a crucial quality for supporting ongoing experiences of everyday reminiscence. Recent research [81] has pointed to *pre-interaction* – the expanded set of experiences that could be designed for prior to interaction in the first phase of anticipation – as a productive design quality for priming reminiscence by prompting people to interpretatively connect elements of personal data to prior points in their life (and vice versa). While promising, only a handful of design artifacts exist that mobilize this approach (e.g., [17, 79, 84]) and none have explored it in the context of location histories. Our work extends this growing research area by concretely demonstrating new forms of pre-interaction (and anticipatory interactions that may follow) that can prime memory-oriented experiences with personal location history data in valuable ways.

7.1.1 Memory Tracer: Combining Randomness, Temporal Expression, and Pacing to Gradually Interweave Moments from the Past, Present, and Future. Prior HCI research has shown how randomness can operate as a resource for catalyzing reminiscence and reflection with large archives of personal data [65, 84, 114]. Yet, in our case, making Memory Tracer's *moment* selection algorithm entirely random in an unbounded way would have rendered each *moment* to have no reference to which date or year in the past it originates. Memory Tracer illustrates how unique, evolving pre-interaction experiences could emerge through randomly selecting a near future calendar day that a *moment* occurred on in the past; and, then using the *moment's* historical 'age' as a factor shaping the number of days until the *moment* is revealed. In other words, a day in one's *future* is tied to a specific time and place in one's *past*, that is experienced in the *present* through ongoing cycles of *tracing* and *revealing*. This quality can trigger various experiences to accumulate around Memory Tracer in the pre-interaction phase.

The early stages of a *moment's tracing* (and tracing tempo) supported anticipatory reflections over which future date the 'day

in history' might be anchored. The map progressively showing more—indicating that the *moment* would soon be revealed—showed promise to prime retrospective reflections that cut across life experiences from prior years that were situated around a particular calendrical date (or set of nearby dates). Such encounters could give rise to a range of recollections–from where one may have been and with whom, to considerations of how one's life has changed across years around this point in the calendar, to simply recalling fuzzier associations tied to a particular season or annual event. These open-ended experiences of everyday reminiscence ranged from a few fleeting moments prompted by casual notice of a nascent visual trace to deeper reflective considerations as a potentially recognizable map-based *moment* came into perceptual view and its relative age could be inferred through the tracing tempo.

7.1.2 Memory Compass: Foregrounding Geographic Awareness to Prime Interactions with Moments Across Space and Time. Memory Compass also has a minimal interface, form, and aesthetic, though it is notably different through adopting an *implicitly slow* design quality that enables user control of retrieving specific spatial-temporal *moments* in their past. These qualities could prompt a remarkably different form of pre-interaction that was more geographic and embodied. After configuring the casting filters but prior to enacting the cast, we could be compelled to pause and reflect on our current location, geographic orientation, and what specific moments in our past might come back. This memory-oriented way of contemplating geographic space and place over time, configured how we thought about the relations of our own life stages and memories tied to places across time, which could lead to cycles of interaction and reflection. These ranged from anticipating other geographically clustered *moments* that could be retrieved through similar casts after an initial *moment* triggered a significant recollection, to simply adjusting the strength or orientation of the cast in anticipation of the surprising discoveries that might be revealed. Our own movement through space also led to an increased awareness of how location shaped the *moments* returned to us. This was particularly revealing when the first author temporarily moved from where they had attended university to their family home, thereby shifting the relative 'nearby' *moments* more easily accessible via shorter casts from recent, largely mundane, moments in their life to a rich pastiche of places bound to their earlier formative years.

7.1.3 Comparison of Explicit and Implicit Slowness as Design Qualities for Supporting Everyday Reminiscence with Location History Data. Collectively, the insights generated through our design led process demonstrate an advance for how the HCI community can leverage qualities of pre-interaction and anticipation to design for everyday reminiscence. Memory Tracer illustrates how pre-interaction can be mobilized and extended not only through subtle, gradual changes in the design artifact's output (e.g., light-based visual changes) but also through leveraging the pacing itself as a form of shifting temporal expression. These qualities can come together to prime experiences of reminiscence on past experiences bound to places that continually recur and diverge across the calendar year, and which subtly expand as the location history archive and user age over time. The case of Memory Compass shows that users can be extended a degree of control in ways that do not compromise the ability to support experiences of pre-interaction that prime reminiscence. Memory Compass' minimal design paired with spatial and temporal filters as well as one's own embodied sensibility for retrieving *moments* through casting, generate a sense of unpredictability that supports cycles of anticipation and reflection. Equally, these design qualities could prime a space for reflection prior to casting, where a user can anticipate what might emerge from their past in relation to their present geographical orientation.

In this way, our work bridges research on designing for pre-interaction with techniques for supporting interactive cycles of anticipation and reflection. There is a need for future research to explore how these combined techniques can be used to create new applications that support experiences of everyday reminiscence with location history data. The combined creation of both Memory Tracer and Memory Compass – and the different perspectives on location history they generated – suggest there are opportunities for exploring how multiple design artifacts with differing design qualities could work together to enable users to develop rich memory-oriented perspectives on, pathways through, and interactions with large and growing personal history data archives. There is an opportunity to develop design patterns that illustrate how people can move among *ceding autonomy to explicitly slow systems*, like Memory Tracer, that make time for pause and reflection through uncontrollable, gradually changing expressions of location histories, and *to enacting control of implicitly slow systems*, like Memory Compass, to anticipate and explore different moments in one's history across space and time. Beyond creating new systems and artifacts for supporting everyday reminiscence, future research could extend concepts for slow technology by contributing to the call for more diverse exemplars of how speed and pacing are conceptualized and how more temporally diverse design strategies can be enacted [16, 67, 99, 101, 125].

7.2 Tools for Getting a Grasp on Location History as a Design Material

Our practice-based design research revealed a need for new interactive tools to better support interaction designers and researchers in industry and academia working with location history data. Our early experiments for organizing and working with location data were incredibly crude on a tangible and visual level. This part of our design process required developing ways to parse and grapple with different elements within huge JSON files, that comprise location history data. This initially hampered our sensibility for understanding and working with spatio-temporal aesthetics of location history data and the potential value they could have as a resource for everyday reminiscence. In working through these challenges, we decided to create a framework for classifying location data as *moments* and *location days*, which ultimately informed our final designs.

We iteratively created a range of visual assets that helped us grasp what location history data is, and we developed techniques for organizing location history archives into different spatial, geographic, and temporal formats. These experiments ranged from map-based representations to visual traces of one's locational movement across days, weeks, and years. This helped us get a handle on how we might conceptually and practically deal with the sheer size and scale of location history datasets. Another challenge we encountered centered on the changing stability of location history data.

Many months into our design process, Google Timeline introduced several changes in the way the data was stored and structured. This required us to adjust and refactor our code for classifying and surfacing *moments* from the archive.

These collective issues present very real complications that challenge the capacity for design researchers to create new relations to and perspectives through personal data. These challenges intersect with calls for more diverse and extensible approaches for "breaking data free" in the service of creating stable versions that can be safeguarded, creatively manipulated, and given new and unexpected forms [24, 126, 127]. Building on recent work situating data as a design material to be better understood through practice [16, 26, 63, 88, 115, 127], there is an opportunity to create new interactive systems that support designers in organizing, visualizing, and prototyping different spatial and temporal patterns, themes, and variations in large personal historical archives. Like how our early experiments in working with location data to understand what it 'is' (through visualizing it on map-based representations) were critical in developing interaction and experience designs, such resources and tools could actively support the development of richer inspirational resources that can be scaffolded in the next stages of the design process.

While GPS and GIS data visualization tools exist, they are cumbersome and not well suited for the creative, fast-moving explorations that are needed in the early stage of the design process. We imagine tools that will not only enable designers to diversify and extend their capacity to work with data as a design material, but equally help generate opportunities that better respond to calls in the design research community to create design artifacts that exemplify rich and diverse alternative expressions of personal data in everyday life [30, 31, 51, 60, 105]. Indeed, researchers have already begun to develop initiatives to support designers in getting a grasp on the immateriality of data, algorithms, and network connectivity [13, 28, 36, 90] that could be leveraged in support of future research in this direction, as could research on developing tools for designers [72, 109].

7.3 Ethical and Logistical Challenges of Personal Location Data as a Design Material

Finally, we critically reflect on key ethical and logistical challenges of recording and using personal location histories that we encountered through our research.

7.3.1 Tensions in the Adoption of Location Tracking. While the security around any form of personal data (documents, photos, music, etc.) is important, location data poses a particularly high risk due to its ability to reveal a magnitude of sensitive personal information bound up within the data. Naturally this may make people resistant to using location tracking services such as Google Timeline [42]. There is a tension between the value of recording a personal log of one's previous locations and the fact that this data is often collected and stored by organizations driven by economic incentives to profit from that data. While there are still few devices and applications which meaningly leverage location data, the personal value of generating it can often be unknown to the end user.

7.3.2 Security and Access to Location Data. A specific challenge we encountered while using Google Maps Timeline data during the research, was the lack of an API. This posed an inconvenience for us as designers – we needed to occasionally login to Google Takeout and manually export and download our most recent data. This was, however, a positive trade-off for us as the owners of our data – we knew our entire location history could not be accessed, unbeknownst to us, by an unscrupulous third-party software. However, giving end users better options on how to store and sync their private location data with other devices and services is needed. There is an opportunity for exploring new options to securely backup or sync the data directly from one's mobile phone (where it is being recorded) to external devices, without ever sending it to a remote server. If all data remained encrypted and computation occurred locally on personal devices, collectively these could be starting points for *data intermediation* [64, 120] – where personal location histories are aggregated and put back into the hands of end users.

7.3.3 No Universal Format for Location Data. Another current challenge is that there is no universal format for location data, even though there have been attempts, namely GPX [44] and KML [61]. Custom JSON or CSV formats are often used when a user requests an export of their data. Additionally, services occasionally change their own formats, which happened with Google Maps Timeline during our research. This inconsistency poses a challenge for designers and end users. Designers need to be comfortable parsing large data sets with custom scripts to easily work with location data as a design material. Users can find it challenging to know how to directly engage with their data—to view and experience it—outside of the application that created it. Both situations can make location histories feel intangible and unable to be owned, explored, and lived with in an ongoing way.

8 CONCLUSION AND FUTURE WORK

Through grounding our practice-based design research in the proposals of *Memory Tracer* and *Memory Compass*, our work contributes to growing calls in the HCI and design communities to create design artifacts and exemplars capable of a) supporting situated experiences of everyday reminiscence and reflection [8, 20, 41, 49]; b) opening broader possibilities for forming relations to our growing archives of personal digital data [30, 31, 51, 88, 105]; and c) extending concepts of slowness and temporality through design [67, 81, 98, 118]. Our detailed unpacking of the Memory Tracer and Memory Compass design cases helps make real differing, yet complementary approaches of using location history data as a design resource for exploring, contemplating, and reminiscing on places bound up in one's life history.

Our research offers new insights on how personal location history archives might be experienced as they continue to evolve and expand, suggesting that location data can offer a valuable resource for supporting everyday reminiscence that can scale over time. A notable limitation of our practice-based approach is that our research is constrained to our own first-hand experiences of making and encountering Memory Compass and Memory Tracer. To address this limitation, in our future research, we aim to conduct field deployment studies of both design artifacts to better understand their potential benefits and limitations through people's real and situated

experiences of them over time. Additionally, our work focused on using a single person's location history data without combining it with any of their other data or another person's location history. We strategically chose the 'limitation' of only using location history as a primary form of data to push the design team on creative, conceptual, and practical levels. There is a clear opportunity for future work to investigate how personal location histories might be combined with other forms of personal data (e.g., notes, voice memos, music listening histories, fitness health data, etc.) to open unique ways for reminiscing on and exploring one's past. Another opportunity for future work is to investigate the social dimensions of combining and comparing location histories of close friends or loved ones.

Importantly, our aim is not to be conclusive. Rather, we aimed to unpack and critically reflect on Memory Tracer and Memory Compass in a generative way to inspire future design research that inquires into the spatial, locational, and temporal expressions of personal data in people's everyday environments. On a broader level, we hope that our critical-reflexive description of Memory Tracer and Memory Compass, and discussion of the resulting opportunities and challenges they raise, can be appreciated as an effort to better support design-oriented forms of knowledge production in the HCI community.

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