Exploring Memory-Oriented Interactions with Digital Photos In and Across Time: A Field Study of Chronoscope

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Figure 1: From Left to Right: The Chronoscope in Alice's bedroom during the deployment; Peering into the scope, the user views photos from her past. Her left hand manipulates a fully rotational gray silicon surface (rotating clockwise moves 'forward' in time and rotating counter-clockwise goes deeper into the past); The display inside visualizes the central photo's location in time and provides corresponding data; Its user interface includes the central photo, its timestamp on the top left, its location data, and the current mode it is in. The user can rotate the scope to move along the photo collection to the right (closer to the present in time), or to the left (back into the past).

ABSTRACT

We describe a field study of Chronoscope, a tangible photo viewer that lets people revisit and explore their digital photos with the support of temporal metadata. Chronoscope offers different *temporal modalities* for organizing one's personal digital photo archive, and for exploring possible connections in and across time, and among photos and memories. We deployed four Chronoscopes in four households for three months to understand participants' experiences over time. Our goals are to investigate the reflective potential of temporal modalities as an alternative design approach for supporting memory-oriented photo exploration, and empirically explore conceptual propositions related to slow technology. Findings revealed that Chronoscope catalyzed a range of reflective experiences on their respective life histories and life stories. It opened up alternative ways of considering time and the potential longevity of personal photo archives. We conclude with implications to present opportunities for future HCI research and practice.

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CCS CONCEPTS

• **Human-centered computing** → Interaction design; Empirical studies in interaction design; Interaction design; Interaction design process and methods.

KEYWORDS

Digital Photos, Memories, Temporality, Interaction Design

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1 INTRODUCTION

Since their emergence in the 19th century, photographs have operated as resources to support people's practices of self-reflection, social interaction, identity construction, and contemplation of the future [9, 23, 122]. Today, people's photographic practices are highly

mediated by digital devices and services. These digital technologies have enabled people to accumulate personal photo archives at scales larger than ever before. For instance, it is estimated that 1.72 trillion photos are now taken worldwide annually, and 89% of the photos were taken with smartphones [16].

These massive and still growing digital archives pose new challenges for the Human-Computer Interaction (HCI) community. As people's digital photo archives continually grow larger, they become formless and placeless, lacking the material presence that might invite people to notice and engage with their archive as a resource available in their everyday lives [83, 106, 122]. This tension can also introduce challenges for people to grasp how expansive their digital photo archives are and what experiences, histories, and things are documented within them [89]. Recent research has shown that the widespread adoption of smartphones and low-cost availability of cloud storage over the past decade has accelerated the growth of personal photo archives [10], which further amplifies existing tensions. These shifts also generate new opportunities for people to reflect on memories bound up in their photo archives that document a considerable breadth and depth of life experiences over numerous years. However, there is limited knowledge on what strategies or concepts could help guide design research to better support and sustain reflective experiences with large photo archives. Growing work in HCI has argued there is a need to develop alternative design approaches that better support open-ended experiences of reflection, interpretation, and slowness when revisiting their digital photos archives (e.g., [32, 56, 84, 112, 113, 116]). In parallel, as interactive technologies have become embedded in people's everyday lives, researchers have proposed it is necessary to "investigate what it means to design a relationship with a computational thing that will last and develop over time – in effect, an object whose form is fundamentally constituted by its temporal manifestation." [71, p.11] Yet, examples illustrating how such engagements with personal photo archives can be mediated through the creation and study of new design artifacts remain sparse in the HCI community.

Our research aims to contribute precisely to this intersection through investigating three main objectives. First, we want to inquire into how making people's digital photo archives more materially present and interactive with different temporal modalities might open new possibilities for reflective memory-oriented photo viewing; in this, we attend to how photos work as cues that trigger autobiographical memory in situ. Second, we aim to better understand how temporal metadata could operate as a resource for potentially generating a renewed sense of awareness and control over large and still growing personal digital photo archives. Third, we want to pursue personal life history as an aspect of temporality raised by *slow technology* [48, 85] and inquire into how this framing might offer a rich way to support experiences with digital photo archives that change over time. To this end, we aim to empirically explore conceptual propositions related to slow technology design theory.

To pursue these research goals, we conducted a three-month field study of *Chronoscope*—a design artifact that leverages the timestamp metadata attributed to each photo from when it was originally taken to open up new ways of experiencing the lifetime of digital photos in a person's archive (see Figure 1). Motivated by prior research on slowness and temporal design [47, 71, 85], key qualities of Chronoscope's design include: *takes time to understand*; *manifests change through time*; *modulates pacing of sequential movement through time;* and *generates interconnections across different forms of time to prompt reflection on their presence in everyday life.*

Taking inspiration from the focal way people use scope-like objects, Chronoscope is a near eye interactive photo viewer that enables users to revisit, navigate, explore, and contemplate the various memories bound up in their personal photo archives across time. As shown in figure 2, a cornerstone of the Chronoscope design is its three interconnected timeframe modes that enables the user to organize and interact with their digital photos through chronological (*Linear*) and non-chronological (*Date, Time*) forms of time. Importantly, when a new mode is selected, the center photo-in-view does not change, while the surrounding photos are replaced with ones from the new timeframe. This, in effect, enables the photo-in-view to operate as a kind of anchor point that creates interconnections across different timeframe modes. Chronoscope offers direct control to the user to change the timeframe modes and the position 'in time' within their photo archive whenever desired. This creates an opportunity for the user to explore a range of possible connections across different photos taken at different points in time in their past. Yet, Chronoscope's design remains relatively minimal. It takes time to understand, recognize, and interpret memories bound up in one's massive and still growing digital photo archive.

We created a batch of four Chronoscope *research products* [87] and deployed them in four households for three months, using them to open a dialogue with participants about the open-ended, reflective potentialities of memory-oriented photo viewing technology; and, to probe on their experiences of living with this design artifact over time through the lens of slow technology. Findings revealed that Chronoscope became integrated into participants' everyday practices and catalyzed a range of reflective experiences on their respective life histories and life stories. They also showed that perceptions of Chronoscope subtly changed over time and opened alternative ways of considering time and the potential longevity of personal photo archives. This paper makes two contributions. First, it provides insights on how a design artifact can support memory-oriented photo viewing by making one's digital photo archive accessible through different temporal modalities. Second, it offers a case that helps expand strategies for designing slow technologies that can be accepted into people's lives and change with them through time.

2 LITERATURE REVIEW

The related work falls into four sections: digital photos, memory studies, personal data, and slow expression.

2.1 Digital Photos and Interactive Systems

Digital photographs have existed for decades and represent one of the most prevalent and extensive forms of digital possessions that people have. Thus, it is perhaps no surprise that digital photos have received considerable attention in the HCI community and, more broadly, the social sciences and humanities. Numerous researchers have described the varied roles digital photos play in supporting

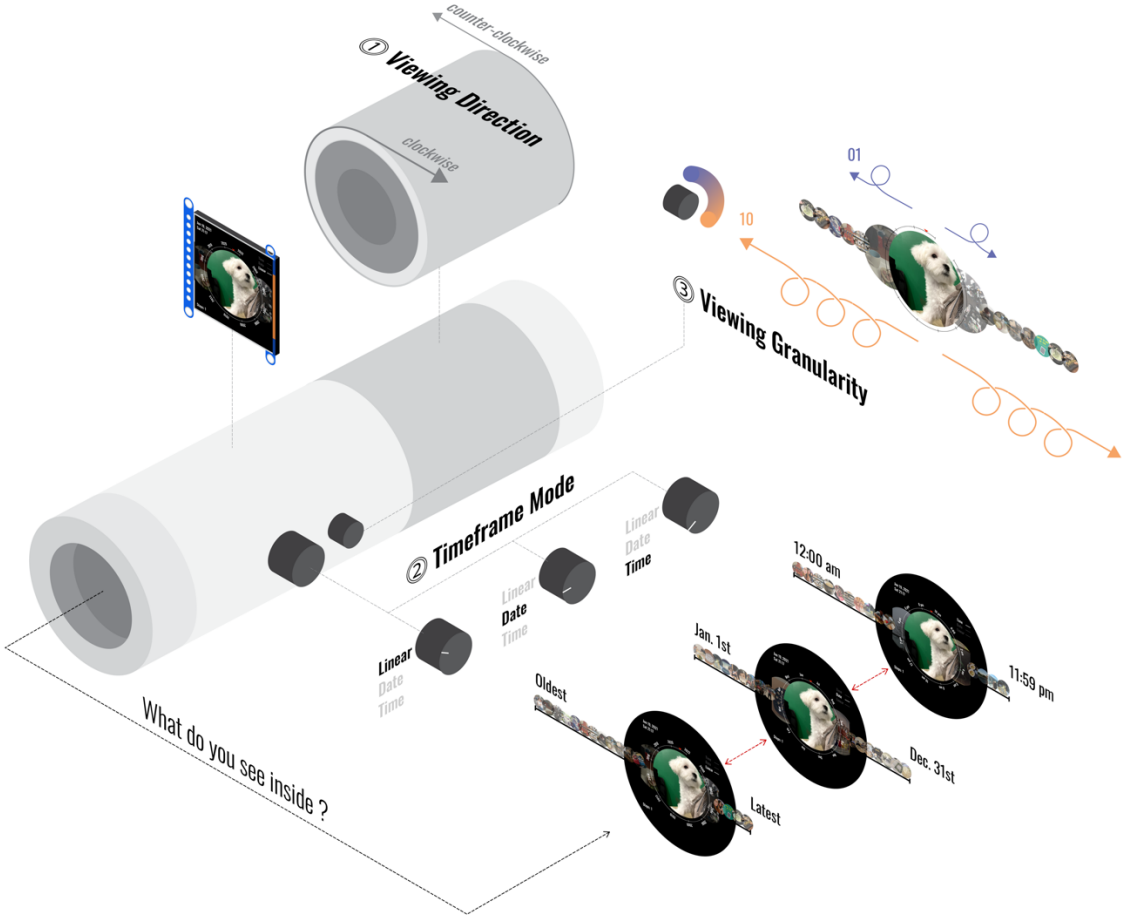

Figure 2: There are three physical controls that work together to enable a user to explore their photos in and across time (and they dictate what is shown on the embedded display):① The viewing direction is decided by which direction the wheel is rotated (either clockwise to more recent photos, or counter-clockwise to older ones with the selected timefame) ② The timeframe mode (Linear, Date or Time) is selected by the larger black knob.③ The smaller viewing granularity knob controls how many photos the user navigates across in a single rotation within the selected mode. In the lowest setting, 1 photo and at the highest 10 photos are moved through; this applies in clockwise or counter-clockwise movements.

identity construction (e.g., [25, 26, 51, 119]) self-growth (e.g., [24, 70, 117]), practices of personal and collective remembering [3, 14, 27, 28, 76, 118], as well as developing a cohesive life story over time [5, 54, 55, 103, 104]. HCI researchers have also long been interested in how people's everyday interactions with digital photo capture, storage, and organization could be improved (e.g., [36, 69, 117, 119]).

Despite the valuable and diverse resources that digital photo archives can offer, the exponential growth of digital photos has made it difficult for people to access and engage with their vast collections [15, 122]. Recent research by Bergman et al. [10] has shown that the adoption of smartphone has only exacerbated these difficulties as the production and proliferation digital photos continues to expand. Research has also shown design strategies for navigating large archives commonly mobilized in contemporary photo applications, such as long scrolling galleries of photos, are not effective prompts for remembering past memories [15]. Scrolling galleries require photos to be opened to full screen before they can be fully recognized, which interrupts the experiential flow of browsing, thus limiting the capacity for reminiscence [3]. Other common strategies, like digital slideshows, overcome this tension by displaying photos in higher resolution, but introduce different complications—showing only one photo at a time can cause people to lose the narrative context across the photo set which limits person-centered and episodic forms of remembering [1, 3]. Further, slideshows require a subset of photos to first be curated from a large collection which diminishes capacity for spontaneous and serendipitous remembering experiences [3]; and, more generally, people tend to abandon efforts to manually curate digital photos [10].

Design researchers have begun to investigate strategies to address these complex tensions and better support interactions with people's photo archives that can scale over time. One key strand of

research has focused on investigating how tangible interactions can be designed with personal digital photo archives [7, 57, 73, 84, 123]. A limited selection of design research projects, such as Photobox [84], ReFind [121], Memora [53], Photoswitch [30, 31], and Fenestra [114], have shown the value of increasing the physical presence of digital photos in people's everyday lives through the creation of new design artifacts. These works have begun to illustrate how the combined qualities of form, materials, and interaction can lead to increased interactions with and perceived value of their digital photo archives as well as with the design artifact itself. Yet, they only focused on resurfacing a single or a small subset of photos in people's life. Another major HCI research area has focused on how tangible interactions with digital photo archives can generate alternative ways to support open-ended experiences, such as locating and sharing memories with digital photos (e.g., [66, 116]), catalyzing social conversations (e.g., [50, 57, 112]), and supporting both individual and social experiences of reminiscence and reflection (e.g., [84, 91, 112, 115, 123]).

Other more recent HCI research has focused on creating interaction technologies for digital photos which include AR-enabled tangible photo viewing [17, 46], two-sided formats for digital photos [44], and novel approaches for supporting photo taking practices such as selfies (e.g., [65, 111]). While most of this research focuses on use-cases involving individual photos or a small number of photos from the recent past, metadata has begun to be explored as a resource for augmenting human-photo interactions with added contextual factors. Tactics such as vote-based photo curation [124], environment-based remembering and searching techniques [58], and multidimensional visualization of photo collections [63] have each been investigated to limited degrees, respectively. These investigations are largely motivated by a practical need to manage and organize digital photos. Yet, few works have explored how metadata, as a context provider, could be used to support more diverse forms of photo viewing and interaction.

Overall, these collective works indicate that, while limited, there is growing interest in exploring new and novel ways to engage people's digital photo viewing experience. They also show the real and complex frictions that come with massive personal digital photo archives, highlighting the need for a multiplicity of approaches that can enable people to get a grasp on their archive and re-experience the memories bound up within it. Our research aims to extend these works by deploying and studying a novel system that supports rich, open-ended interactions with personal photo archives through and across time.

2.2 Memory Cues and Autobiographical Memory

At the intersection of HCI and memory studies, photographs have been investigated as powerful memory cues for autobiographical memory. They are often considered as information resources that aid people in remembering and retrieving key contextual details of a memory tied to one's personal history [102, 105]. Research investigating memory cues has increasingly gained purchase within interaction design, with a particular focus on *external memory cues* – "physical or digital cues in tangible embodiment with an internal effect on memory reconstruction" [61, p.110]. Often initiated by memory cues, autobiographical memory is "memory for the events of one's life [. . .] where considerations relating to self, emotion, goals, and personal meanings, all intersect" [20, p.103]. Taking these concepts in mind, we can see one's personal digital photos as an archive with a growing number of memory cues in it that support people in retrieving memories that, in part, construct their life history [60, 75]. Most contemporary digital photo applications and storage services have been designed to support voluntary recall of autobiographical memories that "follow a controlled, strategic retrieval process" [11, p.279] which involves considerable amounts of intentional searching, editing, and repurposing techniques for photos. Yet, involuntary autobiographical memories, such as seeing a picture with high school friends on a bedroom wall with no preceding attempt at memory retrieval, have been found equally frequent and important in supporting people's everyday remembering processes [100]. People's experience of remembering can be seen as a situated and constructive process [8], and tangible memory cues existing in people's living environments have been found highly effective in triggering involuntary autobiographical memories [11, 60].

Against this backdrop, our research aims to extend this work through investigating the potential and limits of temporal metadata as a type of external memory cue. We explore how a time-based retrospective remembering process might be enabled and supported through leveraging temporal metadata as the key design material shaping interactions and experiences with digital photos. We want to inquire into how different kinds of temporal contextual cues may help situate and interweave digital photos across one's personal history. Thus, we contribute a field study detailing how rematerializing and reorganizing digital photos through a temporal lens shapes people's situated experiences of reconstructing autobiographical memories in their home.

2.3 Personal Data, History and Revisitation

The HCI community has had an ongoing interest in how personal data can be represented to support reflection on personal everyday experiences [22, 34, 45, 89, 99] and life histories [21, 33, 59] in ways that are open to ongoing interpretation [101]. Prior work has focused on the design of technologies that extend data, such as images or audio recordings, to physical cherished objects (e.g., [38, 77, 90, 92]). Researchers have also begun to explore opportunities for enabling people to re-experience digital media from their past with photos, music, and social media (e.g., [59, 67, 86, 109, 110, 113]). Over the past several years, HCI and design researchers have articulated new opportunities for using metadata "as a resource for people to manipulate and personalize their virtual possessions" [89, p.991]. Through the Curatorial Agents project, Gulotta et al. proposed that temporal metadata in particular can be leveraged "as an important factor in the meaning-making process [and] could be a contextual variable that helps situate digital information [for] evocative, meaningful, or relevant experiences." [45, p.3460] Collectively, this research helped open opportunities for seeing metadata in a new way for design – not simply as a byproduct of the creation and use of personal data, but as a potential design material for supporting new ways of viewing experiences from one's past from different perspectives. Elsden et

al. argue there is a need to investigate the design of interactions with personal data that expand beyond "an exclusive interest in performance, efficiency, and rational [self] analysis" [35, p.48] and that emphasize interactions with personal data "representations that support multiple perspectives rather than reductive explanations" [35, p.47]. Elsden and colleagues later extend this work to articulate the design approach Documentary Informatics [32] where they propose key opportunities for future research: (i) exploring the role that data could play in shifting orientations to photography as a technology of memory [118] and (ii) giving data a fixed form to enable it to settle in place [107] as an ongoing part of everyday rituals and practices.

Leveraging different kinds of metadata as filters to supporting alternative ways of data *wayfaring* [99] has also been proposed as a key opportunity area for generating new ways of reflectively orienting to key events, threads of history, and lifelong practices bound up in large archives of personal data [35]. Nascent design research has begun to show the promise of creating new technologies capable of supporting more nuanced and alternative interpretations of personal data in ways that can grow and change over time. The Olo Radio project [81, 88] explored how metadata could be a resource used to reorganize and re-surface music that had been previously listened to in one's past through different forms of time. This work opened new ideas about how metadata could be a design material for supporting memory-oriented interactions with digital media from one's past in open-ended ways. The design and study of Slide2Remember unpacked how a wall-mounted photo viewer could randomly shows a user's photo paired with a song that was listened around the same time when the photo was taken [68]. This project demonstrated how pairing two forms of personal digital media that were bound to a similar point in time can support situated experiences of reminiscence. In both instances, by emphasizing the *presence*, *coexistence*, and even *sequence of* different digital instances based on their creation date, these design cases showed how to use temporal metadata as a strong resource to reorganize, resurface, and reconnect people with their personal life history more meaningfully. Yet, to date very limited research on metadata exists in the context of digital photos.

Our work seeks to directly build on this prior research and contribute a field study investigating how temporal metadata, embodied through Chronoscope, instantiates a 'place' to have open-ended experiences with vast personal digital photo archives. We discuss opportunities for memory-oriented photo archive interactions and 'wayfaring' through a temporal lens, and the roles that alternative representations of personal data could play in opening a space for exploring one's life history from different perspectives over time.

2.4 Designing for Slowness and Temporality

Bound up in a personal digital photo archive, the scale and depth of different points in one's life history are what motivated us to explore how digital photos could be re-experienced through a diverse temporal lens. In their foundational research on *slow technology*, Hallnäs and Redström proposed "a design agenda for technology aimed at reflection and moments of mental rest rather than efficiency in performance" [48, p.201]. This vision was extended through the critical argument that design practice must embrace a longer temporal trajectory to create "technology that surrounds us and is part of our activities over longer periods of time" [48, p.203] and ". . .that will last and develop over time" [71, p.11]. Since these foundational works, there has been a growing interest in exploring slowness and temporality as frames for the design of new technologies. Galani and Clarke [39] applied a slow technology framework to catalyze imaginative experiences through an augmented reality museum installation. Grosse-Hering et al.'s Slow Juicer [43] and Pschetz and Banks' Long Living Chair [94] each mobilized slowness to give rise to meaningful reflections on embodied practices with each artifact respectively, and prompt reflection their one's relation to them over their lifetime. Taking an analytical approach, Huang and Stolterman [62] utilized visual representation to examine temporal patterns and usage.

A handful of works have explored how slowness could support meaningful experiences with digital data. Examples including the Reflexive Printer [113], Photobox [84], Olly [86], and Postulator [50] provide evidence that slowness can be a resource for supporting rich experiences, such as anticipation and reflection. Yet, these systems enforce a 'slow' pace by restricting nearly all control people have over the system itself. Recent research has advocated for the need to create new approaches for advancing the high level aspirations of slow technology through design in ways that offer people some control over the system, while not compromising the richness of this approach [85, 88, 93, 95, 112]. Pschetz and colleagues [13, 95] offer a salient argument that projects aimed at designing for slowness may result in an oversimplification of the dichotomy between fast and slow by treating 'time' as solely a matter of pacing. Extending this argument, Rapp [97] proposed new opportunities for temporal technologies to enable more "malleable" representations of time with added control over the velocity of the interaction pacing. Collectively, these works highlight the need for research that explores temporal diversification through design and people's lived experiences of it.

Our work aims to contribute to these strands of research on slowness and temporality. Through our field study of Chronoscope, we want to explore how chronological and non-chronological expressions of time can be used as frames to engage people and design temporally diverse interactions with vast digital photo archives.

3 METHODOLOGY

Building on our previous work which unpacked the initial design of Chronoscope [19], we conducted a long-term field study of people's experiences with a highly finished version of this device. Instead of taking a user-centered design approach that often makes design iterations based on a small number of short-term laboratory results, we adopt the concept of *research products* [18, 87]–design artifacts that are created to drive a research inquiry in a real-world context and that have a high quality of finish such that people engage with them over time as is (i.e., a thing), rather than what they might become (i.e., a prototype). Research products are created to operate independently for substantial time periods to support long-term field studies in people's daily environments. In extending prior work, we created a batch of new Chronoscope research products that are highly robust and resolved. Next, we summarize key parts

of our design process to highlight important qualities of our final version of Chronoscope.

3.1 Design Process and Implementation

Our own framing and design of Chronoscope is influenced by conceptual propositions that we arrived at through close readings of the theoretical articles on slow technology [47, 71, 85]. An abbreviated and synthesized set of propositions that shaped our framing are as follows. Slow Technology is a technology that: *takes time to understand*; *manifests change through time*; *modulates pacing of movement through time;* and *generates interconnections across time in everyday life*. In line with these conceptual aspirations and inspired by recent work that extends a theory of slow technology for design, we are interested in building in support for controlling *temporal modalities* – where "the integration of one or multiple different forms of time are the cornerstone of an artifact's interaction design" [85, p.174] – and *temporal interconnections* — which "opens the possibility for interconnections to form and expand across all instances of digital media or data embodied by a design artifact across multiple dimensions of time" [85, p.174]. Prior research has speculated that these conceptual propositions may come together to "project a co-evolving quality that is unique and distinct to the user, that takes time to interpret, and that can scale to evoke cumulative change over time" [85, p.174]. We want to understand how these design qualities might shape participants experiences with Chronoscope over time in the context of their everyday lives with their actual personal digital photo archives. Next, we briefly elaborate on key parts of our design research process and field study.

3.1.1 Integrating temporal modalities and granularities. Chronoscope enables users to explore and interact with their photo archive through three combined rotational controls on *viewing directions*, *timeframe modes*, and *viewing granularity*. When peering into Chronoscope, a single photo tied to the specific time that it was originally taken will be visible (see Figure 3 and Figure 4 for a full scenario of usage). Please follow the numbers and read from top to bottom.

As figure 5 shows, the scope's main feature is a rotating wheel that controls the *viewing direction*, navigating either forward or backward in time within the selected timeframe mode. Navigating in a timeframe mode occurs through a rotational movement (*clockwise* to move forward in time and *counterclockwise* to move backward). This form of physical rotation presents a subtle analogy to the circular shape of clocks and the seemingly perpetual, ongoing temporal flow evoked by their movement. By rotating either direction, the user sees each photo slide horizontally in relation to a wide spectrum of other photos in the archive. To 'speed up' or 'slow down' the amount of photos that are cycled through in one rotation when manipulating the *viewing direction* clockwise or counterclockwise, the user can adjust the smaller knob to 'tune' the granularity. This can, in effect, enable a user to move through their photo archives in very slow and meticulous manner if, for example, they encountered a set of photos that triggered deep reflection or examination. Equally, the control allows quick movement across vast amounts of photos without an excessive rotation, while retaining a subtle awareness of what had been passed over. This 'tuning' feature, termed *temporal granularity* [19, 85], opens up more freedom and flexibility for the user to move through photos from minutes in a day to years of one's life.

When the user stops the rotation, Chronoscope settles on the specific photo associated with where 'in time' the position is in relation to the selected timeframe mode. When switching the bigger knob on the side of the scope, users can seamlessly toggle between different temporal organizations of their archive through three timeframe modes (*Linear, Date, Time*). *Linear* organizes in a linear timeline, from oldest to most recently taken. *Date* structures all photos in a temporal ordering based on the Month and Day they were taken irrespective of the year, potentially offering a more 'calendrical' way of exploring photos in one's archive. *Time* organizes all photos based on the specific time of the day they were taken irrespective of date or year, opening a space to explore the rhythms and qualities of past experiences that cut across moments bound to parts of the daily 24-hour cycle.

Despite the three different types of controls, Chronoscope's experience design remains relatively minimal. It does not direct or point the user to a particular point in time. As more photos are accumulated in the user's everyday life, they continually form connections to different points in time across the three timeframe modes. The temporal granularity 'tuning' knob further extends control to enable the user people to develop a sensibility for their own desired interaction pacing when moving through time periods and across different interconnected points within their life history. Motivated by the need to *create technology that requires time to understand* and becomes part of people's practices over long time periods [71, 85], the aim of these underlying decisions is to use minimal guidance for users in our final design in hopes of catalyzing a range of experiences that can scale and change as Chronoscope, and the photos manifested through it, are better relationally understood over time.

3.1.2 Crafting a small batch of Chronoscope research products. We crafted a batch of Chronoscope research products to investigate how different forms of temporal cues might shape people's real and situated experiences of recalling memories bound up in their personal digital photo archives. We started from a scope-like physical form because it critically suggests rotation-based tangible interaction and invites users to view and contemplate their past memories in an intentional, inquisitive way. Illustrated by figure 6, we integrated a Raspberry PI Zero W that was connected to and controlled components that include one 1.54" TFT 240x240 color display that shows the user interface, one rotary encoder attached to the rotating wheel, one rotary switch that decides the timeframe mode, and one potentiometer that supported 'tuning' the temporal granularity. We also integrated a lithium ion cylindrical battery, a PowerBoost 1000 charger, and a latching pushbutton for power to allow for portability. After numerous iterations of prototyping Chronoscope's physical enclosure with PLA and ABS to fine tune tolerances, we fabricated the final form from 3D printed resin to create a strong structural integrity and to evoke a weighty, steady feeling when hand-held. We also hand-made silicone covers for the eye piece and the main viewing direction's rotational mechanism to provide a softer, inviting texture when in use.

In parallel, we developed a Python script that securely requests, downloads, processes, and integrates each respective participant's

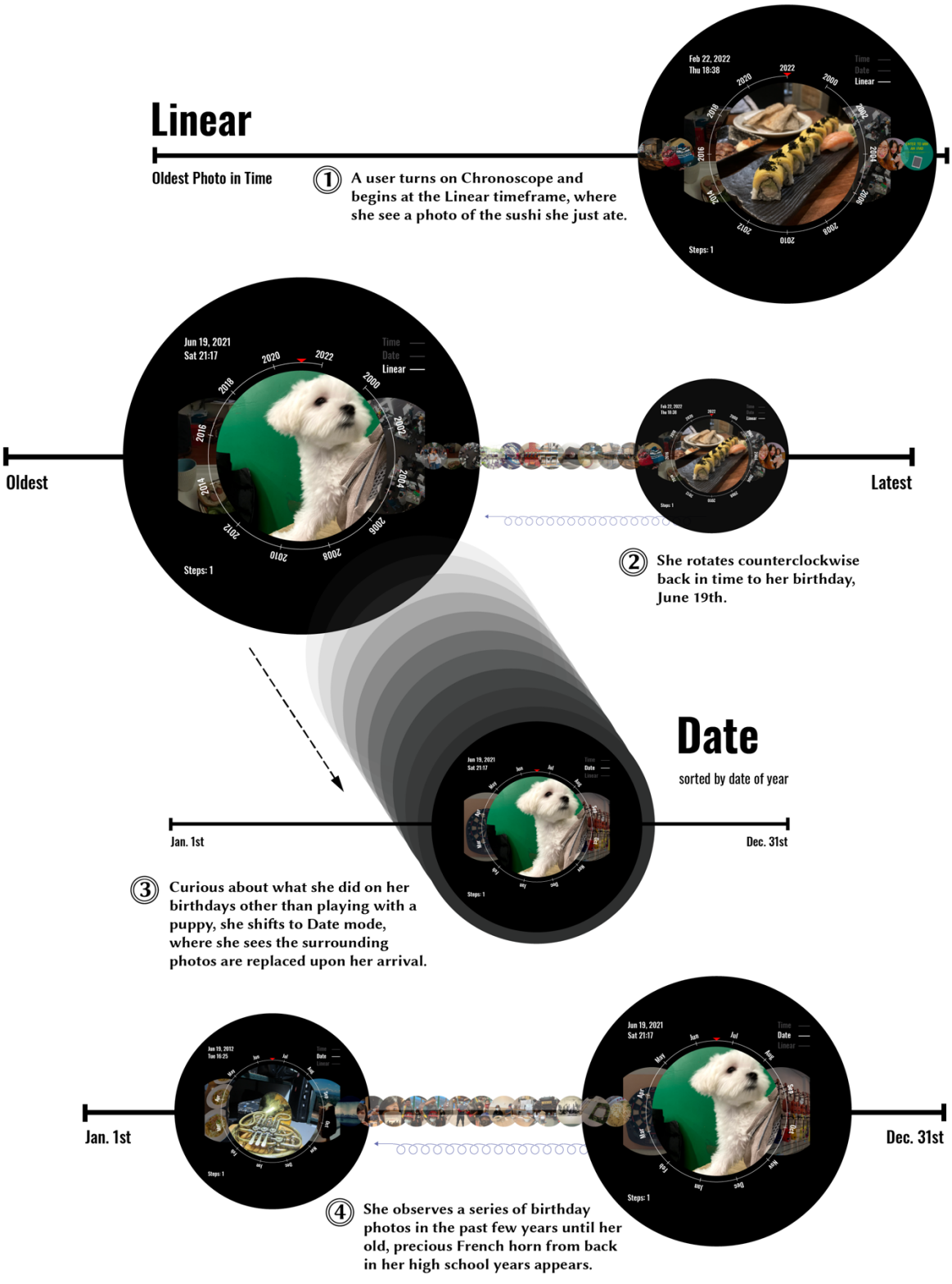

Figure 3: First part of the scenario of moving across the three timeframe modes.

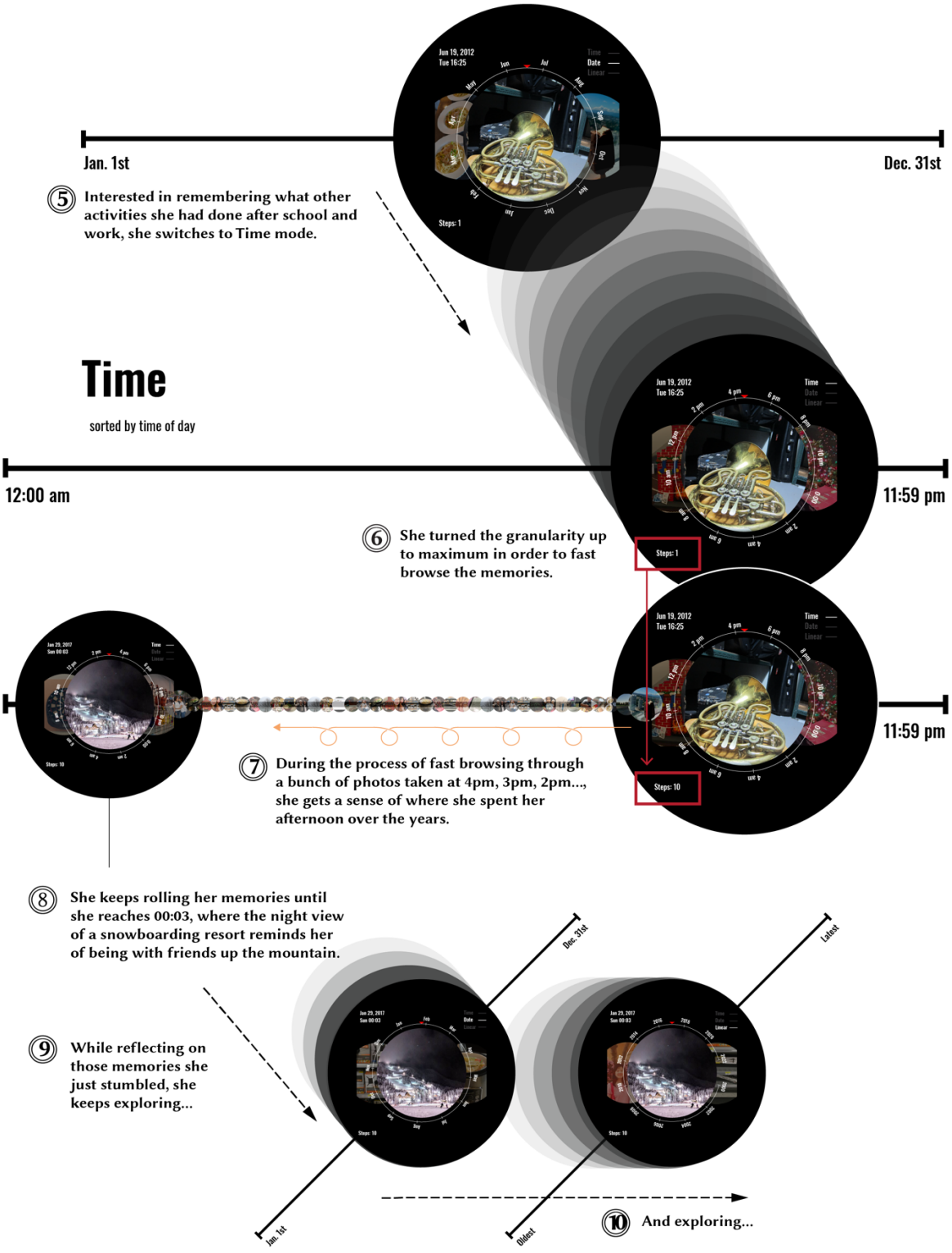

Figure 4: Second part of the scenario of moving across the three timeframe modes.

Figure 5: Four Chronoscope research products with color variations were created to support memory-oriented experiences with photos through different temporal qualities and by re-materialization of digital archive.

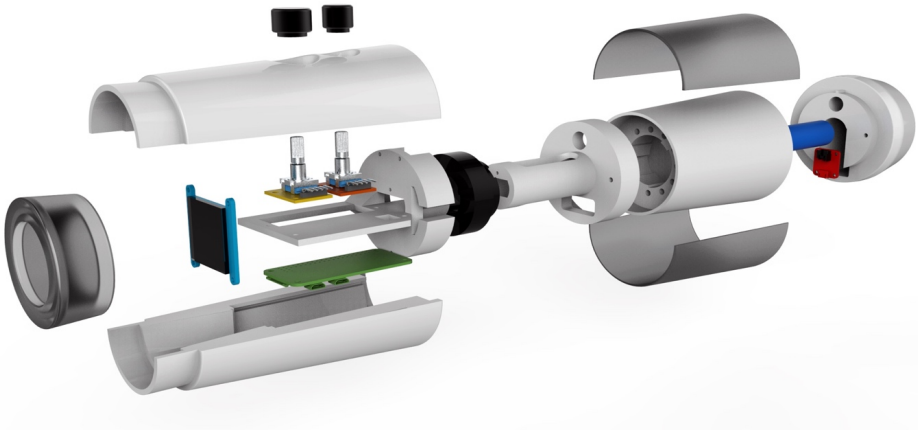

Figure 6: An exploded view of the final research product version of the Chronoscope design. From left to right: silicone eyepiece with magnification lens is affixed to the 240x240 color display; Pi Zero W is integrated under a rotatry switch (for timeframe mode selection) and a potentiometer (for granularity selection); these compontents lead into a continuous rotary encoder that is integrated into a driveshaft (for photo viewing selection); a cylindical lithium ion battery, Powerboost 1000 charger, and latching pushbutton (for powering on and off) conclude the electronics implementation. The enclosure is fabricated from 3D printed Resin with the viewing direction rotational surface encased in silcone.

digital photo archive onto Chronoscope. The script essentially creates smaller thumbnails of each digital photo and integrates each with a relational database that is organized and interconnected via the three timeframe modes. We wrote this script to directly interface with either Google Photos or Dropbox. When Chronoscope is turned on, it automatically synchronizes photos with the selected cloud service if there are any new photos. The decision to use these services creates the limitation that participants in our study must have one of these photo storage services and have used it for years. Yet, this decision also provided several important benefits. First, both services are widely used and have existed for over ten years, enabling people to accumulate large photo archives within them, often with little maintenance. Second, these systems generate consistent, easily accessible temporal metadata that are preserved across all digital photos uploaded to them, irrespective of the device or devices that a user may have used to originally take photos (e.g., camera, tablet, smartphone, etc.). Third, these services offer APIs that enabled us to efficiently access and maintain an always up-to-date photo archive on each participant's respective Chronoscope. This third point is especially important because each time a participant takes photos, they are uploaded to their archive and become present within their Chronoscope as photos accumulate over time, forming interconnections to other photos across the Linear, Date, and Time modalities.

Collectively, these design decisions of Chronoscope features enabled us to (i) generate a quality of change over time, (ii) connect everyday photo taking practices to the temporal qualities of photo viewing through Chronoscope, and (iii) probe on participants' perspectives on the origins of their digital photos, their movement to the cloud, and the subsequent re-materialization through Chronoscope's presence.

3.2 Participants, Data Collection and Analysis

We recruited 4 participants from a large city in Western Canada in our study. Similar to the aim of the original technology probes paper [64] and several design-oriented field studies that have followed (e.g., [40, 49, 52, 84, 113]), we first focus on a smaller selection of participants to gain a rich, descriptive understanding of the space

Table 1: Participant Profiles

Participant	Alice	Clara	Porter	Bell
Age	mid-30s	late-40s	early-30s	mid-30s
Gender	female	Female	male	female
Occupation	hotel/restaurant supervisor	music educator (pianist)	product photographer	grad student in education
Daily Schedule	rotating/shift	freelance	fixed / 9-to-5	flexible
Living Environment	apartment with one roommate	shared house with her teen son	house with wife's family	shared house with her partner
Timeframe of Photos	2014-2022	2006-2022	2009-2022	2013-2022
Number of Photos	9,921	5,302	2,965	10,932
Cloud Service	Google Photos	Google Photos	Google Photos & Dropbox	Dropbox

as a whole to inform future research and practice. We recruited participants through word of mouth and online advertisements. In this paper, we use pseudonyms to describe participants. We selected these participants because, taken together, their respective digital photo archives and photographic practices had showed considerable diversity in terms of size and age (See Table 1).

We aimed to collect descriptive accounts from participants about their experiences with Chronoscope over time. Each participant had a Chronoscope connected to cloud-based digital photo archive. In the initial interviews, we learned participants' photographic practices and, more generally, their daily lives and practices. Participants gave us a home tour and we set up their respective Chronoscope's connection to Wi-Fi in their preferred domestic location (see Figure 7). We offered a demo of Chronoscope and provided a pamphlet explaining how it works. However, we did not require participants to use or interact with Chronoscope. We explicitly noted that they could develop their own interpretations of Chronoscope based on their interest in using (or not using) it. All were aware they could drop out of the study at any time.

After the initial visit, we conducted bi-weekly interviews over 3 months to check in with participants. We aimed to probe on the degree to which Chronoscope prompted reflective, temporal reminiscence, or other memory-oriented experiences over time. We were also interested in whether unexpected connections across photos were revealed or if participants encountered photos that they did not remember taking to understand how these experiences were reconciled. The final in-depth interviews lasted for approximately two hours. Two researchers attended and took field notes in each interview. Fieldnotes were reviewed immediately after each interview, and tentative insights were noted in reflective field memos [42]. We referred to fieldnotes and recordings that captured participants' earlier experiences to explore potential changes in their attitudes toward Chronoscope. All interviews were audio recorded and saved confidentially to a secure storage unit. After getting a set of verbal transcripts from an automatic transcribing service named Otter.ai, we manually corrected the mistakes and misinterpretations in them. The final transcripts were then coded by two members of the research team, using a hybrid approach involving first deductive and then inductive coding. After each home visit with our respective participants, we conducted a preliminary analysis, including a search for themes that stabilizing and shifting patterns across our data that were later drawn out as underlying themes [74]. We coded raw documents with these themes and created affinity diagrams to model connections and differences among participants. Ultimately, this process yielded thirty-one codes and eight themes in total.

4 FINDINGS

Next, we present examples taken from field interviews that help best illustrate themes in our findings, with a focus on how Chronoscope mediated experiences of photo viewing related to navigation, reminiscence, and time. To help better contextualize the thematic findings, we begin with a brief overview of our participants' general orientations to their current digital photo archives.

4.1 General orientations to digital photo archives

In our initial interviews, all participants communicated highly valuing their digital photos, but also noted key challenges that prevented them from engaging with these archives. These frictions essentially boiled down to two factors: 1) a lack of motivation due to the sheer size of their photo archives and the amount of labor involved, and 2) a lack of awareness around the precise contents of their expansive photo archives. These sentiments are summed up well by **Bell**:

> "I have camera auto-upload because I don't want to lose any of the photos that I take. I always have the intention that one day, we go back and look at them, but that never really happens. Even if I review my photos, I don't go back to 2014. I go to probably last year or something like that just because the sheer amount of photos I have." (**Bell**)

Among four participants, Clara exhibited the strongest desire to have control over her archive. She frequently reviewed photos, deleting the unnecessary ones, on her Google Photos account over the past several years with the goal of building a stronger relationship with them through these curatorial actions. However, even a meticulous photo organizer like Clara experienced difficulty engaging with her photo archive. She characterized her current interactions with digital photos as largely being attempts at managing them.

Figure 7: Left to Right: Clara's scope on her kitchen table; Porter's scope under his desk in a shared office; Bell's black scope in her study.

Yet, the more management controls that were offered, the less in control she felt:

> "I try to control everything, but when I check the photos here [in my archive], I see how powerless I am, especially over time. . . You can just let it happen, and let it go. You actually have no power to control anything. The only thing we can do is keep is the photos." (**Clara**)

The tensions expressed by our participants stemming from lack of control over and awareness of their personal digital photo archives matches findings from prior HCI research [10, 15, 89, 122]. Collectively, they show that current tools available to them fell short of addressing the sheer scale and size of their respective photo archives and triggered feelings of powerlessness. Yet, all participants were inclined to continue generating and accumulating digital photos in the long-term. Next, we present findings that detail the range of experiences that participants reported having with Chronoscope in and across our field study.

4.2 Integrated patterns of use and shifts in attitude over time

Prior slow technologies have encountered tensions that complicate their acceptance and adoption as frustration emerged for participants due to a lack of control over the devices they lived with (e.g., [41, 50, 80, 84, 113]). Chronoscope extends a considerable amount of control to participants, yet the interaction design is highly open-ended, and the multiple forms of time mobilized to organizing and exploring one's photo archive would take time to understand. While Chronoscope provoked a variety of responses, participants reported integrating Chronoscope into their everyday lives early on in our study. Participants kept Chronoscope in various places, such the bedroom (**Alice**), home office (**Bell**), or shared creative space (**Porter**). After approximately one month in our field study, participants often described a turning point where they came to self-determined understandings of Chronoscope. For **Porter** this turning point was triggered by the perception that Chronoscope instantiated a physical place to collate, connect, and recollect memories bound up in their photo archive. Here, he reflects on the challenges of finding meaningful photos across multiple Cloud services and the role Chronoscope began to play in resurrected a memory-oriented practice that had faded away:

> "I was jumping between Dropbox and Google Photos. . . .It's hard to find them [as they're] scattered [across] services. Usually, I send the pictures to the friends and family that was involved. After that, I don't usually go back. . . .It [Chronoscope] reorganized the events and kind of reconstructed those memories. I think it [viewing photos on Chronoscope] is more emotionally connected somehow, either with a person or a particular event I remembered." (**Porter**)

Similarly, **Bell** described how the tangible presence of Chronoscope facilitated ongoing interactions that progressively led to new insights emerging around different temporal modalities shaped relations to her photo archive:

> "Because it is a physical thing, it lives here. I see it all the time. . . .Chronoscope really comes in to help me to be in reflective mindset, so I really appreciate it. It's become part of my habits now. . . .At the beginning, I didn't really understand what it means to have Date and Time [modes] just because I think we're not used to seeing photos that way. So, they [the modes] helped me to learn different ways of relating to my photos, [and] just think outside the box." (**Bell**)

As **Bell** continued, she discussed how experiences with Chronoscope had begun to shape her photo taking practices. Her reflection illustrates a shift in attitude toward connecting the new photos she takes now with the different points in her past, and how these qualities come together synergistically to create a unique 'footprint' of her sense of self:

> "Last Saturday, I went to celebrate a friend's birthday. When I was taking photos, I feel like later I'm going to be able to relish this memory because of the gadget I have at home from three different vantage points. . . .I definitely welcome it [Chronoscope] to live with me. I will totally have it in my life because right now a lot of things that we have are dedicated to so many different things. This is dedicated to one thing. It represents a unique footprint of me, and I cherish being able to have access to that." (**Bell**)

Collectively, these examples help illustrate that, despite its open-ended design qualities, Chronoscope became integrated into participants' lives. Its physical presence showed potential to reinforce a sense of ownership over participants' digital photo archives and to

reinvigorate prior memory-oriented interactions with digital photos. They also demonstrate Chronoscope could provoke reflections on how one's life history and digital photos can become entangled across over time. Next, we explore this theme more deeply through describing different kinds of memory-oriented photo viewing experiences that participants reported on.

4.3 Memory-oriented interactions in and across different temporal modalities

Bell's quote in the prior section touches on the individual and collective capacity for Chronoscope's timeframe modes to provide various temporal 'vantage points' on digital photos and the memories bound up in them. As our study progressed, it became clear that Chronoscope's timeframe modes gave rise to different, yet at times overlapping, ways of remembering, exploring, and interconnecting life experiences. Yet, timeframe modes could also take time to make sense of, at times causing frictions around their intelligibility and intention. Next, we present examples that best highlight participants' perceptions and attitudes towards various memory-oriented experiences Chronoscope provoked.

4.3.1 Noticing and journeying through changing life stages. Participants often described their experiences using Linear mode—which chronologically organizes their photo archive—as traversing 'waves of time' (**Clara**) where they were able to quickly move across many seasons, birthdays, important events, and so on. For **Bell**, these experiences took on a 'journey-like' quality that provoked her to develop a narrative for interpreting the trajectory of life experiences she encountered and navigated across:

> "When I was going through the Linear mode, I actually feel the journey of my life. I'm reminded that there's a big picture there. I feel all kinds of emotions. I feel really grateful and very fortunate to be able to experience all the things that I have experienced, but also being able to experience that again, when I was going forward in time [with Chronoscope]." (**Bell**)

Bell's reflection exemplifies instances where participants reported gaining an extended awareness of the scale of memories captured in their photo archives. Participants also reported on experiences that focused in on key episodes in their respective life stories which often marked a progression through life stages that came with shifting priorities:

> "I can see my life path through this Linear mode. I realized in my early 20s, I'm always traveling, going to different countries, doing different kinds of things outdoor with my friends or my family. But after certain years, my photos become much less than before. . . .which means I [am] getting busier and have less time [for travel]." (**Alice**)

Clara noted that while the rate at which she took photos remained constant, she noticed a distinct shift in 'what is important' in her life over time. As an accomplished pianist, she reflected her shifting orientation toward piano playing prior to and after her son was born:

> "I'm not focusing on myself anymore. It just happened naturally as time goes by. You focus on yourself. You want to make yourself better. But then gradually, you stand out to look at the world and want to look for many other things, instead of just for yourself. . . .I came across one picture of my recital many years ago, and I don't do recital anymore now. But l still play piano. I still teach. . . .I still do very similar things, but you know, it's totally different now — I have a different purpose . . .seeing that change through my photos showed I present myself differently now." (**Clara**)

These examples illustrate how participants leveraged Chronoscope to examine traces of their past self and to move across different life stages. This, in turn, could lead to a broader overall awareness of scale of memories within the archive as well as meditations on one's history in relation to the current lived present. Next, we dig deeper how non-chronological timeframe modes mediated participants' photo interactions and remembering practices.

4.3.2 Serially exploring annual events, forgotten mundane moments, and contemplating future actions. Participants used Date mode to explore significant episodic life events. Yet the capacity to explore these events relationally, in series, across years supported alternative ways of navigating and remembering momentous past experiences. **Porter's** reflection is exemplary of this theme:

> "It's like I'm going to each event individually in the Date mode but across time. They [photos in archive] are sorted continuously, so I can have a sense of almost like a flashback to each event and how they're woven together. . . .Labor room in hospital, birth of baby, . . .lots of birthday celebration pictures and baby pictures on October 29th, which is my son's and wife's birthday. Viewing them in Date mode, I felt a sense of happiness and joy of becoming a father. . . .As I went through the pictures this way, it showed me so many good memories from back in Asia, during [different] Chinese New Years all together. It makes me want to make more meaningful memories with loved ones." (**Porter**)

In contrast to focusing on significant annual events (e.g., birthdays, holidays, etc.), **Bell** leveraged Date mode to explore the many mundane, yet valued moments between them:

> "I don't take myself as someone who does a lot of selfies. When I used it [Chronoscope in Date mode], I was like. . . oh, there's a selfie. Oh, there's another one. And a lot of it is just random [shots] of me and my partner. . . .It really reminds me of the mundane, joyful moments. It's those moments that we tend to forget, we tend to remember the bigger memories, the more memorable ones. But I think that it is those like tiny ones that are very worth "tasting". In Chinese, we will say 'hui wei', [which means] we can go back and taste the nice little surprise. And I'll show it to my partner: You remember we took that photo? What were we doing?" (**Bell**)

Interestingly, **Alice** also described using Date mode as a resource to probe into what she had recorded about her life on particular

dates in the past to get inspiration for planning dinners, parties, and surprises for friends in the near future:

> "When I want to plan an event for a specific day, I definitely will use the Date mode to check what I've done in the past. . . .There are some special days that I really like to celebrate every year. For example, my birthday, Thanksgiving, Christmas and Chinese New Year . . .I don't like to always do the same things for same days. So date mode helps me to avoid doing the same things and get some new ideas." (**Alice**)

However, tensions did arise when people tried to search for specific dates that were meaningful but in a different calendar system. **Bell** shared that:

> "I realized I couldn't [find] Lunar New Year because [it] uses [the] lunar calendar. It's actually different days every year, so it's cool to reflect on the difference in seeing time. But still, I just went to that general day frame lunar year usually happens. And I think because I couldn't really celebrate lunar new year [this year due to COVID-19]. . . I think being able to go back and see how I celebrated it, and seeing a whole chunk [of photos] in there all at the same time, was very comforting." (**Bell**)

Collectively, these examples illustrate how participants explored past life experience —both momentous and mundane, if not totally forgotten— as they serially cut across calendrical time with Date mode. They also exhibit considerable diversity from **Porter**'s contemplation of momentous life events viewed in series, to **Bell**'s approach to enacting 'hui wei' to encounter surprises 'in between' dates that are traditionally regarded as important, and to **Alice**'s practice of viewing records of her actions of past dates to inform her future actions.

4.3.3 Discovering everyday patterns, element of surprise, and seeking change with Time Mode. Time mode, which organizes all photos based on the time of day they were taken irrespective of the date, required the most amount of time for participants to understand. Initially, **Clara**, **Porter**, and **Bell** experienced challenges in interpreting this kind of non-chronological temporal modality. For the majority of participants, these frictions eventually faded as our study progressed and often new insights were revealed about their actions tied to different periods in the day. **Clara** describes how her perception shifted from viewing Time mode initially as 'random' to noticing distinct moments of growth in her piano teaching practice as well as similarities in her routine that spanned over a decade:

> "For me, at first it was more like, checking pictures randomly. Actually, no order! When I'd try to find some photos, it was hard to do it in this way. It was more like a game of guessing. . . .But then I found when I teach [piano lessons], I sometimes take photos to show my students. Look at your hand shape! . . .those photos showed how they moved and improved. . . .in this way, [Time mode] is more dynamic, it shows pattern and real routine. . . .In Linear or Date mode, we find the time waves, right? But for here [in Time mode], it's like you're jumping but you still see similar things. And it's a short routine in your one day, every day or every afternoon. . . .Even in ten years, I found there are parts of the day I'm doing the same thing! [laughs]." (**Clara**)

In other cases, the somewhat unpredictable quality evoked through exploring photos in a cyclical way bound within a 24-hour frame could create an 'element of surprise' and lead to experiences of anticipation over time. Here, Bell reflects on discovering an array of largely forgotten morning-time activities she engaged in over the past decade which helped motivate her to be more resilient when facing an artistic rut:

> "The element of surprise is always there [in Time mode]. . . .Finding out that I've actually done a lot in the morning was very encouraging. And I didn't just waste my morning time all this time. Once upon a time, I did stuff! It brings up a lot of emotions, a lot of feeling grateful, feeling like. . . okay, let's keep going. I feel encouraged. I feel motivated by my past self. I'm not alone. I really appreciate being able to find patterns across my days. I had all these good feelings because I am able to experience my journey through this unique slice of time I didn't expect." (**Bell**)

While unfamiliar at first, Time mode opened new interactions for participants as they explored different conceptualizations of time (e.g., work time, leisure time, social time) across their collective photo archive. This could, in effect, lead to experiences of anticipation, self-affirmation, and new insights into everyday patterns and routines in ways that cut across over a decade of photos. Next, we explore participants' experiences between and across different timeframe modes and the role this interconnectedness played in shaping their memory-oriented engagements with their respective digital photo archives.

4.4 Cumulative experiences with Chronoscope: modulating pacing, exploring interconnections, and speculating longer-term relations

In addition to offering different temporal modalities to organize and interact with one's digital photo archive, Chronoscope enabled participants to modulate the relative pacing that they moved through their photos across time. In our prior work, we speculated that integrating control over this quality of interaction (termed 'temporal granularity') could help prevent users from getting 'stuck-in-time' – a tension surfacing when a photo archive's density is so great that it would be considerably challenging to move to another time period (e.g., where they may be thousands of photos that would require thousands of rotations or presses of a button) [19]. In this field study, we found all participants made use of the temporal granularity knob to modulate their movement through time surrounding different life episodes, life events, and mundane periods in their respective archives. **Bell's** reflection is exemplary in how it captures frictions emerging from getting stuck-in-time and inventive workarounds that participants developed to alleviate these tensions:

> "I turned on [my Chronoscope] and wanted to explore around 2:15 [in Time mode]. But the first photo was at 10 o'clock. I was like, Oh, 10 o'clock, that's a few hours from 2:15. Cool. Two minutes later [after rotating Chronoscope continuously], it's at 10:01. I took many photos at 10:02! It's taking forever to get there. . . .I was sitting in my office and my partner asked me: what are you doing? I'm trying to get to two o'clock right now! I figured out I could change it to Linear mode, find a photo around two o'clock and change it back to Time mode. . . .Now, I usually have it [granularity] to the largest, which is 10 because it gives me kind of quick view, a broad brush across time. And then if I see something in there that I want to focus on, then I make [the granularity] smaller so I can go back and focus on that time [period] in my past." (**Bell**)

Clara described the value of being able to oscillate between the slowest and fastest interaction pacing with the granularity knob, noting the different, often contrasting, forms of memory-oriented experiences they could surface:

> "Yeah, about slow and fast. I like how [with] slow, I can find a thing, a time in my life, and look in at it. With fast, I like how I can compare experiences, you know, move back and forth quickly over 10 years. I can see a huge part of my history in a short time." (**Clara**)

As our dialogue continued, **Clara** remarked on how using the various interaction modalities of Chronoscope came together as a synthetic experience to shift her perspective on the potentialities of interacting with digital photo archive – a shift toward new forms of *engagement with* as opposed to *management of* photos. This, in turn, led to a greater sense of *agency* over her digital photo archive and a desire to potentially expand her everyday photo taking practice:

> "In my own experience of using Chronoscope, [it] offers agency. It gives new opportunities to reflect on those memories [in photo archive], not just managing and deleting something new. . . .Chronoscope connects everything [in my photo archive] together. It strings together a context of connections for people to orient and move around from these different perspectives in time." (**Clara**)

In our final interviews, participants also discussed and reflected on the temporally interconnective qualities of Chronoscope which bound each photo to three separate points in time in the photo archive. These instances were often characterized by unexpected, yet profound experiences of bringing together multiple threads in time in a participant's life history in a synthetic, immediate way. **Porter** described landing on photo of his wedding, only to find another photo of his parents immediately in the periphery (while using Date mode). The juxtaposition across time of these two distinct memories was seen as highly significant:

> "It has been a long time since I saw my parents together. We're a satellite family[1]. My Dad visited twice in 10 years. . . .The picture [in the periphery] was taken by phone in 2016 before my wedding in [large Canadian city depicted in the main image]. This picture was before a milestone in life (getting married) and it reflects on how much my dad has sacrificed the family time to provide for us overseas. These pictures together mean to me that I want to be there for my kids and try to make it work, but also that I have fond childhood memories when [my parents'] whole family was living together." (**Porter**)

The qualities of personal history, interconnection, and life transitions captured in **Porter's** experience with Chronoscope also emerged in other interviews. **Clara** describes an intriguing interconnection formed by Chronoscope (here, in the Time mode) where she metaphorically and practically saw herself moving off stage through a photo of her on stage as a music performer being connected in sequence with her more contemporary role as a music instructor:

> "Everyone has some glorious moments in life. But it's so different now and [that comes out] when looking back photos from different times in life. I mean, for example, the photos of the recitals. When you stand on the stage, and it feels so proud, or nervous, or happy. But when you check the picture now, it's a totally different feeling considering the other photos surrounding it. You see what you do now in life and what you did years ago. Now, what I see [in the older recital photo] is everything behind that stage scene, like how much time I devoted, how much time I spent in the practice room, and how I picked that dress." (**Clara**)

Porter described how the temporal qualities of Chronoscope created enough context for loved ones, beyond their own life, to potentially make sense of their photo archive and intelligibly engage with it:

> "If I give my photo archive to the next generation, I wouldn't just throw [in] everything and give it to them. I know if I'm handing down my Chronoscope, [the timeframe modes are] something that's connecting me and my photos in a way that a person can understand." (**Porter**)

For **Bell**, the passing down idea reminded her of the importance of having intimate family conversation and of knowing what has actually happened in both familial and societal histories.

> "[My time with Chronoscope has made me] imagine a scenario where, because photos are documented digitally [and temporally] organized, instead of going hours and hours with the fixed physical photos, you will have something that captures someone's life through time, and then be able to find [and] historicize times in their life. . . .When I was a kid, my grandpa told me tons of stories about him being in the Civil War... before Taiwan became Taiwan, when he was still in China. And as a kid, I didn't appreciate that at all. I wish I actually cherished those moments. But

[1]A 'satellite family' is a form of distributed family organization where the primary income earner does not live in the same geographic place where most family members are located at.

> if he had something like it [Chronoscope] that he could've handed off to me, I would give anything for it. . . .All of these [photos] are all clued into the historical moment that we live in. Even though you're looking at someone's personal photos, the time [frame] modes give you just an idea of what's happening at the time from this person's positionality and identity, and how they experienced time. And this has great potential for us to be able to tap into things that can change, like the way personal history does." (**Bell**)

Alice contemplated the longer-term viability of her photo archive operating as a resource for reminiscing on the trajectory of her life history at a point in the future when she is older:

> "When I'm getting older like 50 or 60, I [would] want to go check my youth time more, like what I've done before. It will be more meaningful. I think it [Chronoscope] might work better for people over a certain age, like in their elderly life. I think they will be super happy. But to most young people, they just live at the moment. Their life is too busy to do that kind of romantic thing." (**Alice**)

Collectively, these examples show that participants' experiences with Chronoscope remained valuable over time and illustrate how various temporal modalities generated an evolving quality of interconnection across the memories and associations that make up their life history. These qualities could together to evoke a quality that had a longer-term tail within participants' lives and potentially extending beyond them. Yet, **Alice** makes a salient point—there is a time and place in one's life for reminiscing with digital photos and such interactions may not scale to all generations.

5 DISCUSSION AND IMPLICATIONS

Accessing and interacting with digital photos are essential factors shaping how people locate, retrieve, recollect and share memories. Yet, prior research (e.g., [10, 15, 89, 122]) and our findings suggest that current technology often complicates and limits these practices. Our work offers key contributions that advance current research in the following ways:

- Using temporal metadata as a memory cue to create and trigger journey-based exploration in one's life history;
- Providing ways to support people's exploration of potentially forgotten or unknown life patterns over time;
- Extending the conceptual lens of slow technology through developing more diversified strategies to design with temporality.

Next, we discuss opportunities and challenges for future HCI research tied to these points.

5.1 Creating journey-based interaction design for memory-oriented photo viewing experiences

Prior research has investigated how revisitation of one or a small subset of photos brought reflective value to people's everyday lives (e.g., [84, 113]). Targeting people's relationship with their entire photo archive, our approach extends control over three temporal modalities to navigate unique pathways through multiple memories and life stages. These pathways opened new ways of mediating interactions with digital photos which participants characterized as 'journeys' across their life experiences, such as **Porter's** contemplation of family life after a photo of his wedding was juxtaposed to one of his parents. From here, we see that by providing a particular context of cuing through situating each photo in time relationally with others, participants were able to creatively explore and construct their autobiographical memories with an increased awareness of potential correlations between different life events.

According to our findings, people valued this form of journey-based photo interaction when it resurfaced forgotten or unknown life patterns, especially those in less familiar modes, such as *Date* and *Time*. Because it is not easy to anticipate what photos would be interconnected in those two modes, people can revisit, associate, and reflect on multiple surprising moments at once in their exploration journey, triggering a provocative way of integrating and interpreting autobiographical memories [11, 12, 60]. Through our study of Chronoscope, we offer a design case of using temporal metadata as a memory cue to trigger a journey-based remembering process that brings more curiosity, anticipation, and reflection into play. However, one limitation of using temporal metadata as a memory cue is that the timestamp data are finite and relatively inflexible, which may lead to potential issues in relation to integrating photos taken in different time zones and calendar systems.

Prior research has also indicated that mundane events in autobiographical memories that were repeated, continued into the present, or had an accumulative influence on one's life could be an important but often overlooked design consideration [75]. Echoing this point, **Bell**'s enacting of 'hui wei' to rediscover (or 'taste') mundane, largely forgotten moments with her partner shows opportunities for future design research efforts to leverage concepts of temporal interconnectedness and temporal modalities to further investigate the potential value of re-encountering such mundane moments. While temporal attributes from standardized timestamps encoded within photos are limited (e.g., time of day, date, and timezone), our research has shown they can be effective at providing enough context for people to locate and revisit life patterns, rhythms and cycles while equally leaving space for interpretative, spontaneous, or serendipitous encounters over time. Our study offers early evidence validating the potential of this approach. Yet, clearly there is an opportunity for future research to make use of such temporal attributes to better understand the range of emotional valences and associations that people may experience when navigating across their life patterns and experiences in their digital photo archives.

Our findings also reveal that more built-in support is needed to engage journey-based photo interaction. According to Axtell et al. [4], the combined lack of *user control*, lack of *visual context*, and *manual curation* are key reasons that photo viewing applications (e.g., slideshows, large scrolling galleries, and tabletop) are often not effective prompts for remembering past memories or for spontaneous reminiscence. A key dimension of the Chronoscope design is using *juxtaposition* as a visual technique to generate a sense of peripheral awareness of neighboring photos in the sequence relative to the photo-in-view. This feature is paired with a granularity control to fast forward memories easily. Our findings revealed this subtle technique enabled people to better contextualize each

photo's location in time in a relational way, as described by **Clara** that Chronoscope "strings together a context of connections" and offers *agency* for photo engagement.

However, our design does not offer a way for people to curate or share their photo history. Instead of showcasing a selection of photos as album-based management tools would often do, we see opportunities in providing ways for people to retrace mundane or momentous trajectories to revisit them or to share them with others. In our study, **Alice** and **Bell** both suggested a need to explore photos collaboratively with others, even if from their own personal archive. This suggests an opportunity for future research to investigate how temporal trajectories might be dynamically preserved and revisited as they accumulate over time. Such interactions could give rise to memory-oriented experiences that offer unique comparisons and entanglements of life histories among a group and potentially catalyze collocated social interactions. Future research in this direction making use of temporal modalities can extend prior work on collocated photo-mediated reminiscence which has largely relied on randomness or sequential exploration (e.g., [57, 84, 113]), while also contributing to recent calls for alternative design strategies for collocated remembering [14].

5.2 Supporting longer-term relations with malleable forms of time

Chronoscope's dynamic temporal qualities generated possibilities for participants' relations with it to change over time. It continually updated its archive to represent the entirety of their photo archive each time it was encountered, which connected the present moment to the past. This ongoing quality of change led to a continual reorganization of the archive as each new photo introduced into it was interconnected to other different photos in and across time. These qualities also came together as a synthetic experience for participants that led to increased ownership and agency over their photo archives. This, in turn, led to a renewed interest in their photo archives as they became embodied, changing digital resources to be materialized through Chronoscope in participants' everyday lives. Participants valued the capacity for new photos to be, as **Porter** described, 'stitched' into varied expressions of time in their personal history simultaneously. This led to interconnections forming among memories, experiences, and life stages in both chronological and non-chronological ways, such as **Clara's** reflection on her transition off stage from musical performer to instructor as she noticed sequences of photos capturing the progression in form of her students' hands playing the piano over the years. We found that this design quality came full circle by mediating participant's own photo taking practices, such as in **Bell's** anticipation of where the social gathering photos may end up when interconnected among three different temporal 'vantage points' in the moment she was taking them. Findings also showed that participants valued this ongoing, integrative, and accumulative quality. It is what prompted prospective reflections on the potential longer-term place that Chronoscope could occupy in their own lives and potentially scaling beyond it to future generations.

Collectively, these findings support the vision of slow technology, while offering new insights for temporal technologies that can be investigated in future research. They show that opening a space to explore how a person's life history is bound up in their photo archive with different temporal modalities offers pathways uniquely reflective of the use, that take time to interpret, and that change over time in an ongoing way into the future. Our research contributes a case that builds on and advances ongoing work in HCI that investigated how technologies can find a longer-term place in people's everyday lives and co-evolve alongside them (e.g., [6, 82, 86, 88, 94, 120]). Additionally, due to digital photo archives being immaterial, massive in scale, and proliferated across potentially wide timeframes, we built in support for modulating the pace of movement through time with the temporal granularity control. Participants productively made use of this added degree of control for manipulating their pathways through time – from traversing through many memories across the years to slowing down for conscious contemplation on a specific moment in time. Following Rapp's work [97], these findings validate their recently proposed opportunities designing in control over the velocity of movement through time and enabling users to gain a grasp on more malleable representations of time. Yet, research has also shown that temporal media (e.g., audio or music [88]) and other forms of personal data outside of digital photos will likely require different techniques. More research is needed to investigate design strategies for manifesting the movement, velocity, and malleability of time through personal data; and, following Alice's skepticism over the generational viability, at what touchpoints in one's life such memory-oriented temporal technologies would be of value.

5.3 Mobilizing and extending diverse temporalities across different forms of personal data

Enabling participants to move across different forms of time with the timeframe knob and at different speeds with the granularity control, all while remaining anchored in time by the temporal metadata of the specific photo-in-view supported a range of reflective experiences. Our research validates the proposal from prior work [6, 10, 68] that situating mobilizing a *Linear* timeline-like chronological timeframe mode provided a useful contextual point of reference for participants to navigate their photos. It also builds on recent research [88] by demonstrating that the integration of this chronological modality can be productively scaffolded by participants to interpret and progressively understand the more unusual non-chronological modalities of *Date* and *Time*. Yet, we also found there are limits to this approach. **Bell**'s struggle to locate distinct photo sequences of Lunar New Year experiences across the years in Date mode emerged due to a misalignment between the Lunar calendar with the Western calendrical system that our temporal metadata uses.

Additionally, another limitation that emerged through studying Chronoscope is that it connects photos in a sequence that entirely hides the 'temporal blanks' or gaps in periods when one did not take any photos in their life. Temporal blanks in one's photo archive may hold important meaning in one's life history, such as intentional removal of memories, less interesting life patterns, or fluctuating patterns of when one was awake and active. There is an opportunity for future work to explore how temporal blanks existing in photo archives might be better acknowledged and leveraged as a creative

design resource in photo viewing applications. Collectively, these tensions highlight the critical need for future research to explore the design of new systems that mobilize and express more diverse forms of time as temporal modalities. New design initiatives can build on growing research in HCI that actively investigates the social (e.g., [13, 72]), cultural (e.g., [108]), political (e.g., [2, 93, 95]), and ecological (e.g., [29, 96]) dimensions of time. While there exists a trajectory of HCI research exploring the combination of digital media with different input and output modalities (e.g., [37, 68, 78, 79]), there remains surprisingly little work that has considered what role diverse forms of temporal modalities might play in opening new perspectives on and interactions with personal historical data.

6 CONCLUSION

We studied Chronoscope to explore personal history as an element of temporality raised by slow technology, and to investigate how this framing might offer a generative lens of supporting memory-oriented interactions with personal digital photo archives. Through building and deploying a small batch of Chronoscope research products we were able to gain insights into people's real and situated experiences of their digital photos through a novel temporal lens as well as how their perceptions of both the device and their photo archive shifted over time. Our findings provide new insights into how mobilizing interconnected temporal modalities can offer unique ways of interacting with digital photo archives in ways that overcame limitations commonly experiences with contemporary photo viewing applications that inhibit remembering experiences. They also detail how physical form, digital photos, and interaction can come together in a design artifact to evoke a quality of co-evolving change over time. Our research contributes another step toward understanding how the concept of slow technology can be extended and advanced in design practice and field research. Our research also contributes to calls in the HCI community that call for longer-term programs of design research [98]. Ultimately, we hope this research future work inquiring into the role, place, and pace of digital data in everyday life, over time and into the future.

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