Capra: Making Use of Multiple Perspectives for Capturing, Noticing and Revisiting Hiking Experiences Over Time

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Figure 1: The Capra Collector and the Capra Explorer in use in nature and in the home.

ABSTRACT

As the practice of hiking becomes increasingly captured through personal data, it is timely to consider what kinds of alternative data encounters might support forms of noticing and connecting to nature as well as one's self and life history over time. To investigate this emerging design space, we designed Capra — a system that brings together the capture, storage, and exploration of personal hiking data with an emphasis on longer-term, occasional yet indefinite use. Over four years, our team adopted a designer-researcher approach where we progressively designed, built, refined, and tested Capra. This process produced frictions in terms of balancing unobtrusiveness, transforming hiking data into evolving interconnected elements in the archive, and managing the sheer quantity and diversity of information with our goal of supporting open-ended and ongoing engagements. It is these insights that emerged through the practice-based design research approach involved in creating Capra that we reflect on in this paper.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Interaction design theory, concepts and paradigms.

KEYWORDS

Personal History, Personal Data, Hiking, Research through Design

ACM Reference Format:
William Odom, Jordan White, Sam Barnett, Nico Brand, Henry Lin, Minyoung Yoo, and Tal Amram. 2024. Capra: Making Use of Multiple Perspectives for Capturing, Noticing and Revisiting Hiking Experiences Over Time. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05
https://doi.org/10.1145/3613904.3642284

(CHI '24), May 11–16, 2024, Honolulu, HI, USA. ACM, New York, NY, USA, 27 pages. https://doi.org/10.1145/3613904.3642284

1 INTRODUCTION

Hiking, a journey undertaken by foot through nature, can support self-discovery and connection to the environment where the human-nature relationship is constantly lived out and negotiated [22]. Revisiting records of hiking experiences can enable individuals to reflectively consider how their relationship to nature changes over time [48]. These practices may nurture human-nature relations through newfound awareness [64, 87] and create opportunities for self-growth through recollection of moments spent on the trail [95].

Today we live in a world where the availability of low-cost sensors, mobile, and wearable technologies has led to people's lives becoming recorded, quantified, and aggregated. It is perhaps unsurprising that digital technologies have become interwoven with hiking — whether through navigation applications, fitness trackers, or taking digital photos of vistas and hiking companions, to name a few. As data driven devices increasingly become present in people's experiences in nature, it remains unclear what roles technology could or should play in these contexts. Researchers have warned of technology's potential for disrupting human-nature relations (e.g., [5, 21, 88]), arguing *unobtrusiveness* ought to be a core concept guiding the design of user experiences with technology in nature [43]. Recent work has also articulated key opportunities for designing encounters with data during or after time spent in nature (e.g., [2, 12, 62]). More broadly, as people continue to amass digital records capturing their lives, there is a clear need to investigate how people will retrospectively interact with their "quantified past" [30]. Elsden et al. argue future work must expand beyond "*an exclusive interest in performance, efficiency, and rational analysis* . . .[toward] *representations that support multiple perspectives rather than reductive explanations*" [32:48]. This proposal resonates with recent calls for design approaches reframing data as open-ended, interpretive, slowly evolving, and entangled (e.g., [24, 60, 69, 80, 91]).

As the practice of hiking becomes increasingly captured through personal data, it is timely to consider what kinds of alternative data encounters might support forms of noticing and connecting to nature as well as one's self and life history over time. How might digital records of hiking be captured in ways that offer alternative perspectives on these experiences as they are revisited, explored and lived-with? In what ways, could human-nature relations change as they are considered through different vantage points? And, considering the ongoing engagement with hiking as a lifelong activity, how might the use of personal hiking data unfold, grow, and evolve as a person, their archive, and their memories age over time?

To explore these questions, we designed *Capra* — a system that brings together the capture, storage, and exploration of personal hiking data with an emphasis on longer-term, occasional yet indefinite use. Capra consists of two artifacts: the *Collector* and the *Explorer* (Figure 1). The Collector is a wearable camera device that captures time lapse digital photos during hiking sessions from three different angles, and encodes them with three forms of metadata: temporal (time of day), altitude, and dominant color. As we detail later in the paper, these forms of metadata were both easy to reliably capture on the Collector and offered a set of resources that conceptually supported our goals of revisiting hiking data through multiple perspectives. After being worn on a hike (or hikes), the Collector is inserted into the Explorer which triggers the transfer and storage of recent hiking data within it. During periods of data transfer, the Explorer projects a slowly changing sequence of images that leverage hiking metadata to illustrate relational connections among moments in the new hiking data and the existing archive of hikes. The Explorer is a tangible repository of all hikes captured through the Collector that enables a person to re-visit time lapses of their hikes through three metadata filters: time, altitude, and color. We found these three forms of metadata could lead to a range of potential experiences. For example, exploring the quality of light throughout the day across hikes, contemplating ecological differences at varying altitudes, or non-chronologically orienting through hikes via a color spectrum. These different data-enabled perspectives can be applied when revisiting *a single hike* — offering different durational ways to attend to moments in a hike — or *across all hikes* — enabling explorations of various temporal, altitudinal, and color-oriented interconnections across all hiking data.[1]

A key underlying objective in creating Capra is to inquire into design qualities that might enable personal hiking data to support ongoing open-ended (versus goal directed) experiences — moments of noticing, revisiting, contemplating, and exploring — and how these kinds of experiences might cumulatively shape a person's orientations to hiking in nature. We also wanted to inquire into the long-term relation a person has to hiking over the course of their life as an aspect of temporality raised by *slow technology* [44, 75] and how this design-theoretic framing might offer alternative ways to support experiences with hiking data that change over time.

Over the course of a four year period, we adopted a practice-based designer-researcher approach [15, 40, 77, 83] where we progressively designed, built, refined, and critically reflected on the Capra system – a process that we closely attend to and unpack in this paper. Engaging in the design of Capra produced frictions in terms of (i) supporting *unobtrusive integration and use of technology* [43] while capturing data on the trail, (ii) transforming hiking data into interconnected elements within the archive, and (iii) navigating the sheer quantity and diversity of information that could be captured during a hike with our goal of supporting open-ended and ongoing engagements. It is these frictions and the insights that emerged through negotiating them in the process of designing Capra that we reflect on in this paper. Our work makes two contributions. First, we introduce Capra as a novel system that brings together collecting digital records of hiking in the wild and exploring elements in and across them at home. Second, we trace the development of Capra over four years and interpret insights emerging from this design research process to propose opportunities for HCI research and practice.

2 BACKGROUND AND RELATED WORK

Related work falls into three sections: hiking; noticing; and, personal data.

[1]We encourage readers to view the video archived in the ACM Digital Library with this paper for a dynamic explanation of Capra.

2.1 Hiking

Hiking is an activity that may be engaged with a few times per year, whereas for others hiking can be a lifestyle, occupying most of one's free time [95]. While the frequency at which people hike can vary greatly across life stages, hiking facilitates a cyclical return to nature over time, across one's life. In the HCI community, hiking has been leveraged as a datafied activity that can support technical advances in automated mapping algorithms (e.g., [6, 28, 50]). Hiking has been explored as a social practice that can lead to prosocial interactions [2, 56] and distributed communities [46, 57]. Hiking has also been looked at as an escape from daily life. HOBBIT is a self-described "asocial hiking app" that helps preserve the user's solitude by proposing alternate, less populated trail paths to avoid other hikers [84]. Recently, HCI research has begun to explore design initiatives to prompt reflections on nature when dwelling in the wild (e.g., [1, 3, 19, 92]). This nascent work calls for new research exploring human-nature relations through alternative, interpretive forms of data captured outdoors.

The works reviewed here share the commonality that time spent in nature is beneficial for people and the HCI community may play a role in supporting hiking experiences. Yet, it remains unclear what role technology could or should play. Coyne's essay on "Nature vs. Smartphones" critiques mobile technologies for placing a barrier between people and the outdoors, while also noting their potential to "disrupt, and therefore reveal, aspects of our experience of the natural world" [21:30]. Anderson and Jones articulate an aspirational vision of computing's role in the outdoors where "human-nature interaction holds priority over human-computer interaction" [5:293]. Similarly, Häkkilä et al. propose *unobtrusiveness* must take primary consideration when designing new technologies that mediate experiences in nature [43]. Here, designing for unobtrusiveness requires that technology does not "disrupt or harm any element of the environmental flora and fauna" [43:7] and that all form and interaction modalities must be carefully considered to avoid human-nature disruption. This implication is tempered with the need for more research that develops "UI mechanisms and metaphors" for gaining alternative perspectives on nature. Häkkilä and colleagues contend that future HCI research must respect "the maintenance of natural experiences as a respite from technology . . .[through] exploring the balance between supporting (or mandating) non-use of technology with the potential benefits of technology use" [43:7].

Our work contributes to these intersecting strands of research. We mobilize and extend these design implications through our design process of Capra, exploring qualities and frictions bound up in the collection and exploration of hiking data while attending to the need for unobtrusiveness of technology in the wild.

2.2 Noticing

While the concept of noticing can take on various meanings (c.f., [37, 52, 66, 87]), anthropologist Anna Tsing's 'arts of noticing' [102] has gained purchase in the HCI community as a concept to inspire "the re-examination of research assumptions as a means of pursuing alternative pathways towards preferrable futures" [67:378]. Recent HCI research has explored how arts of noticing can be mobilized in attending to non-human actors in design research (e.g., [10, 19, 26, 67, 81]). HCI researchers have also investigated how *noticing* can offer a strategy for generating alternative perspectives on technological interventions. For example, Livio and Devendorf [68] demonstrate how noticing, as opposed to 'observation', can offer a poetic lens to enact design processes that critically account for human, non-human, nature entanglements in slow and ongoing ways. Rosén, Normark, and Wiberg argue design research is well situated to aid in facilitating "sensory-rich and situated noticing" through creating tangible environmental sensing prototypes [90:12]. In parallel, Liu, Byrne, Devendorf [62] offer a rare example of a design-led approach to exploring noticing through the creation of novel wearable technologies that amplify attention toward the wellbeing of local ecologies. By making and critically reflecting on three design artifacts that refocus a person's experiences in nature toward fungi, soil, and other ecological elements this work generatively inspires the imagination of designers to engage with performative dimensions of noticing.

While diverse, these works are united through their aim to extend design research toward a relational sensibility [4] where nature is not seen as made up of independent objects, but rather as a rich, complex set of interdependent relations. Taken together, they articulate opportunities for designing technology to nurture human-nature relations through priming experiences of noticing, awareness, and connectedness. Yet, to date this research space is limited and more work is needed to establish methods, approaches, and design cases to shape future research practices in the HCI community [10, 67]. Our work aims to contribute to this emerging research area through the design of and critical reflection on an interactive system that aims to redirect attention toward noticing different aspects of nature via one's hiking experiences over time.

2.3 Personal Data, Lived Informatics, and Slow Technology

There exists a range of HCI research on personal informatics. Personal informatics encompasses technologies and practices through which people collect personal data to better understand themselves [61, 71]. Often detailed quantitative records of people's daily lives are generated (step counts, heart beats, daily calories consumed, etc.), which can help users to better understand key life practices (e.g., [8, 97]), biological processes (e.g., [34]), and to accomplish goals, learn, and reflect [72]. Scholars have critiqued personal informatics as being overly rational and too technology centric, which initiated a shift to *lived informatics* — investigating how people make sense of their own data in their own lives [31, 42, 89]. Lived informatics advocates for designing alternative data encounters that offer divergent perspectives on one's life and surroundings. In advancing this critique, researchers have proposed generative directions for future research [29]: (i) exploring the role that data could play in shifting orientations to photography as a *technology of memory* [103] and (ii) giving data localized forms to enable it to *settle in place* [96] as an ongoing part of everyday rituals. Leveraging different forms of (meta)data as filters for *data wayfaring* [89] has also been proposed as an opportunity to open up new ways of orienting to key events, life histories, and lifelong practices bound up in large archives of personal data [16, 17, 30]. Recent research has begun to show the promise of designing interactions

with alternative interpretations of personal data in ways that can evolve (e.g., [47, 80, 101]). Yet, design exemplars in this emerging space are limited and more research is needed to understand how personal data records can be transformed into materials capable of generating alternative perspectives on people's life experiences [29, 32, 91].

A nascent and growing set of works have emerged in parallel that explore how slowness could operate as a conceptual resource to support alternative encounters with personal data. These works build on Hallnäs and Redström's proposal of *slow technology* that argues design practice must change to embrace a deeper temporal trajectory to create "technology that surrounds us and is part of our activities over longer periods of time" [44:203]. Examples including Photobox [76], Long-Living Chair [85], Postulator [45], Reflexive Printer [99], Olly [78] and Memory Tracer [105] demonstrate that slowness can be an effective resource for generating new perspectives on human-data relations that are richly reflective and ongoing. A key design quality uniting these design artifacts is that they each enforce an explicitly 'slow' pacing by restricting nearly all control people have over the system itself. Recent research has argued for creating new approaches that advance the vision and aspirations of slow technology while embracing alternative conceptualizations of temporal structures in the design of interactive systems (c.f., [75, 86, 94]). While diverse, works including Crescendo Expression [14, 98], Chronoscope [17], Olo Radio [80], Soft Fading [24], and PhotoClock [16], illustrate how design practice can productively move beyond treating 'time' as merely a matter of pacing in the service of supporting rich encounters with personal data that scale and change through time. Collectively, these works highlight the need for future research explore how concepts of slowness and temporality can be applied in design practice to support longer-term, ongoing human-data relations that interpretive, emergent, and evolving.

Our work seeks to directly build on this prior research and contribute a reflexive design-led case investigating how personal data can be captured and transformed into rich resources for experiences of reflection, interpretation, and exploration of life experiences captured in nature. We specifically explore how different forms of metadata (time, altitude, and color) can enrich and extend digital records of hikes over time. We also investigate how key design qualities, inspired by concepts from slow technology, supported giving such data a form and place in the collection (with the Capra Collector), the transfer, and the revisitation process (with the Capra Explorer).

3 METHODOLOGICAL APPROACH

We describe our methodological approach as Research through Design (RtD) with an emphasis on design-led research in HCI (c.f., [35, 39, 93, 111]). We adopt a *designer-researcher* position to generate artifacts that investigate and respond to our research questions [15, 23, 24, 77, 105]. 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. Following Archer, a design-led approach can be particularly valuable because "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 test it" [7:11]. Thus, our approach gives prominence to first-hand insights emerging through the creation of real things that materially ground conceptual ideas through their actual existence.

This methodological approach was motivated by several reasons. While related work points to opportunities for creating technologies to accompany hiking experiences — notably through rich encounters with hiking data tempered by the need to preserve the *unobtrusiveness* of technology used in the wild — little research to date has investigated this space through the making of new artifacts to inquire into tensions and possibilities that it may hold. We wanted to understand what forms of hiking data might be 'unobtrusively' collected and how they could be worked with as design resources. What we found is this was a substantial undertaking that came with frictions, emergent insights, and shifts in perspective through unanticipated moves in our design research process. We encountered early unexpected technical challenges bound to our conceptual goals that required time to overcome. This made clear that we needed to adopt a design-led approach to understand the qualities and nuances of the hiking data we were equipped to capture and to account for conceptual and technical precarities as we progressively worked toward creating a research product [79] system that could hold up over time — one open to occasional, yet ongoing use.

Our approach enabled us to understand how key qualities of prototype systems offered promise to support our higher-level research goals. Our position and commitment to offer a detailed reporting of the design journey of creating Capra in this paper 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 investigate emerging issues in HCI (c.f., [9, 35, 36, 39, 40, 77, 93, 110]). With this methodological orientation, we were able to immerse ourselves in the messy, longer-term RtD journey, allowing for an evolving awareness of the process as we designed and reflected on Capra. Considering the longer-term orientation of our research questions, this approach offered a unique opportunity for our team to observe, debate, and critically reflect on the design of Capra — through cycles of seasonal change and growth as time progressed over four years.

3.1 Project and Research Team Background

Our team is composed of seven members whose expertise spans software development, electronics prototyping, interaction design, industrial design, digital fabrication, filmmaking, and HCI research (see Table 1). As a step toward acknowledging the subjective positions inherent to our approach, Table 1 includes a brief description of the cultural backgrounds, expertise, and orientations toward hiking.

We are based at a university in the Greater Vancouver area of British Columbia in Western Canada. Our research took place on the unceded ancestral territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh Úxwumixw (Squamish), səlilw̓ətaʔɬ (Tsleil-Waututh), qʼíc̓əy̓ (Katzie), kʷikʷəƛ̓əm (Kwikwetlem), Stó:lō

Team	Background & Expertise	Approach to hiking
Will	American-Canadian IxD & HCI-Researcher	"I began hiking as a child and progressed into challenging higher altitude hikes as an adult. Now I hike a couple times a month, usually with my own little person."
Jordan	American Software & Hardware Dev.	"I got into hiking at university in the Appalachian Mountains. Since then, hiking and backpacking have become favourite hobbies, particularly to do with friends."
Sam	Canadian & Australian Filmaking	"Hiking is a way I connect with loved ones and experience nature. I grew up hiking in Australia. Now in British Columbia (Canada), I am doing progressively harder hikes across more of the region."
Nico	German Interaction Design	"Since I moved to Canada, I started to go on multi-day backpacking trips. Hiking through lush old-growth and camping on remote Pacific beaches is a grounding experience."
Henry	Canadian-Chinese Digital Fabrication	"Hiking has not only been a way of bonding with friends but has also become a cherished ritual for me. A weekend hike would be a therapeutic escape to unwind after a busy work week."
Min	Korean-Canadian Software Developement	"Hiking had been a casual weekend family activity when I was a child, but this practice has changed as I grew up. I like advanced hiking trails for physical exercise and to beat my own records."
Tal	Dutch Industrial Design	"My hiking is rooted in the practice of 'uitwaaien,': brisk walks in windy weather for mental clarity. In Vancouver's mountains, I discovered a passion for athletically challenging hikes."

Table 1: The Design Research Team. Will, Jordan, and Henry participated in the entire four-year design process. Sam, Nico, and Minyoung participated for the final three years. Tal participated in the first year.

Coast Salish, K'ómoks, Tla'amin, Qayqayt, Kwantlen, Semiahmoo and Tsawwassen Nations. These locations are rooted within Indigenous lands and nations. Hiking trails have been created as a part of settler societies, built within and around green space, while commodifying these locations primarily as sites for recreation and tourism. While signs may be posted on trails to encourage mindful relationships to land and community, they do not typically provide a place to exchange with local Indigenous nations, so special attention should be paid to careful, respectful, and reciprocal responsibilities while hiking. As a part of our process, we informed ourselves through the native-land web application[2] to acknowledge and critically consider the land that we walked on as a part of this project. Acknowledging traditional territories, nations, and lands can be an initial step toward challenging the underlying colonization bound up in standard Western maps, and lead to further exploration and understanding of the history and complex effects of colonialism.

We also recognize that one's engagements with nature and hiking are "made possible by a complex historical, political, social, and economic forces that shape each person's ecological identity, or the way in which we relate to nature" [33:1]. Thus, we must acknowledge the power structures and privileges that shape how people relate to the natural world, and that have shaped our own individual and collective interests in hiking. As part of our process, we debated and discussed our individual cultural and geographical relations to nature and hiking, personal understandings of historical land rites, and the numerous factors that shaped these orientations. Thus, we approach our design research process from a place of privilege and humility — the interwoven narrative of our research team in this paper represents one viewpoint; clearly, a diversity of perspectives is needed within this emerging research space.

3.2 Documentation & Analysis

Following RtD practice, we documented the design research process through weekly notes, photos of sketches, form inspirations, and prototypes, videos of prototyped interactions, weekly presentations of progress and frictions, and notes on technical development. Over a four-year period, we progressively worked through a design process that started with our initial framing and research questions and arrived at the final highly resolved, finished, and robust research product form of Capra.

Throughout this process, as we began to complete prototypes and field test the Collector outdoors, we created a template for documenting, sharing, and organizing notes about our experiences

[2]We encourage readers to explore the native-land web application: https://native-land.ca/about/why-it-matters/

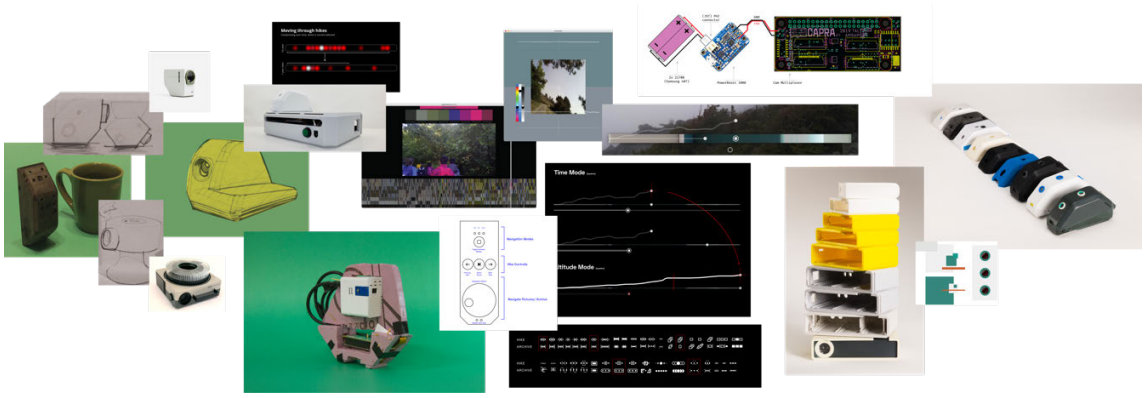

Figure 2: A collage of design artefacts across the full Capra design cycle demonstrating the scale and scope of this design research project including product design, industrial design, interaction design, software design, electrical engineering, graphic design and physical prototyping (which is unpacked and analyzed in 4. Design Research Process). From left to right (loosely): early test 3D print of Capra Collector; concept sketches; objects which inspired the design language; internal graphics created to explain the relationships between metadata and images; screenshot of software prototype; iconography exploration; prototype circuit board diagrams; and evolution of enclosures.

in designing the Capra system. We left it open for team members to document reflective annotations when testing the Collector outside or anytime later when working with data that eventually led to the final form of the Explorer. As this process unfolded, we continually shared our experiences among the research team. We logged reflective annotations through individual journals and, when desired, integrated snippets of imagery (photos, sketches, etc.) to illustrate key insights or reflections. These insights were shared routinely through a Notion workspace [113] and weekly project meetings. We concluded with a summative exchange where we discussed our final impressions across the design research process.

We analyzed the collective insights captured through our Notion board and outcomes from discussions about living with Capra, meeting notes, as well as slide decks, photos, and videos from our design research process (see Figure 2) for an abstracted visual representation of the scope of artefacts collected). This process allowed us to trace back key conceptual and technical decisions and to critically reflect on how they shaped our experiences with Capra. Throughout our analysis, we made note of key insights and events that supported our inquiry in relation to our research questions. We conducted one round of thematic analysis [20] to identity main themes related to frictions and design moves across our process. We also created affinity diagrams to model connections among key insights and events. Next, we present Capra, the rationale that motivated each component, frictions that emerged, and design moves that resulted in the final form.

4 DESIGN RESEARCH PROCESS

We see Capra as a system that brings together the capture and the experience of hiking data in ways that are indeterminate, accumulative, and open-ended. Our aim is to create a space for interactions with hiking data that allows people to explore multiple perspectives via alternative vantage points, sequences, and journeys *in* and *across* their hikes. We want to better understand how technology might be designed to support ongoing interactions with a digital archive over seasons and years, as it expands with growingly unique interconnections across hikes. Our design research process is influenced by the slow technology design philosophy [44] because we are interested in exploring temporal qualities bound up in one's ongoing, cyclical return to nature through hiking and the generation of hiking histories. Conceptual goals of slow technology advocate for creating technology that requires time to understand, changes over time, and oscillates between the foreground and background of everyday life. We also draw on recent research that has begun to articulate design qualities of slow technology [75], specifically *pre-interaction* — a quality that emphasizes designing for the time and space prior to the moment an artifact is directly interacted with; *implicit slowness* — a quality where the end user is able to freely control the design artifact while it still retains its 'slow' character; and, *explicit slowness* — a quality where the design artifact operates on its 'own time' and the pacing cannot be changed; and, *temporal interconnectedness* — a quality where a set of connections across different temporal dimensions can grow and change simultaneously among different digital data over time. Inspired by prior work that bridges design theory and practice through annotating key design decisions with concepts that influenced them [11, 49, 70], we interweave concepts and qualities drawn from slow technology within the accounting of our design process.

Next, we present the three components of Capra, the design rationales that guided their creation, and key design and implementation details. While we include some first-hand experiences with Capra as a part of our design-led approach, it is important to make clear our research is not explicitly an autobiographical (or duobiographical) study. In this paper, we focus on the proposal and creation of the Capra system, aiming to closely attend to our practice-based process, as opposed to a long-term accounting of first person use among the design team. The first-hand experiences we do include were critical to developing rationale for making decisions in our

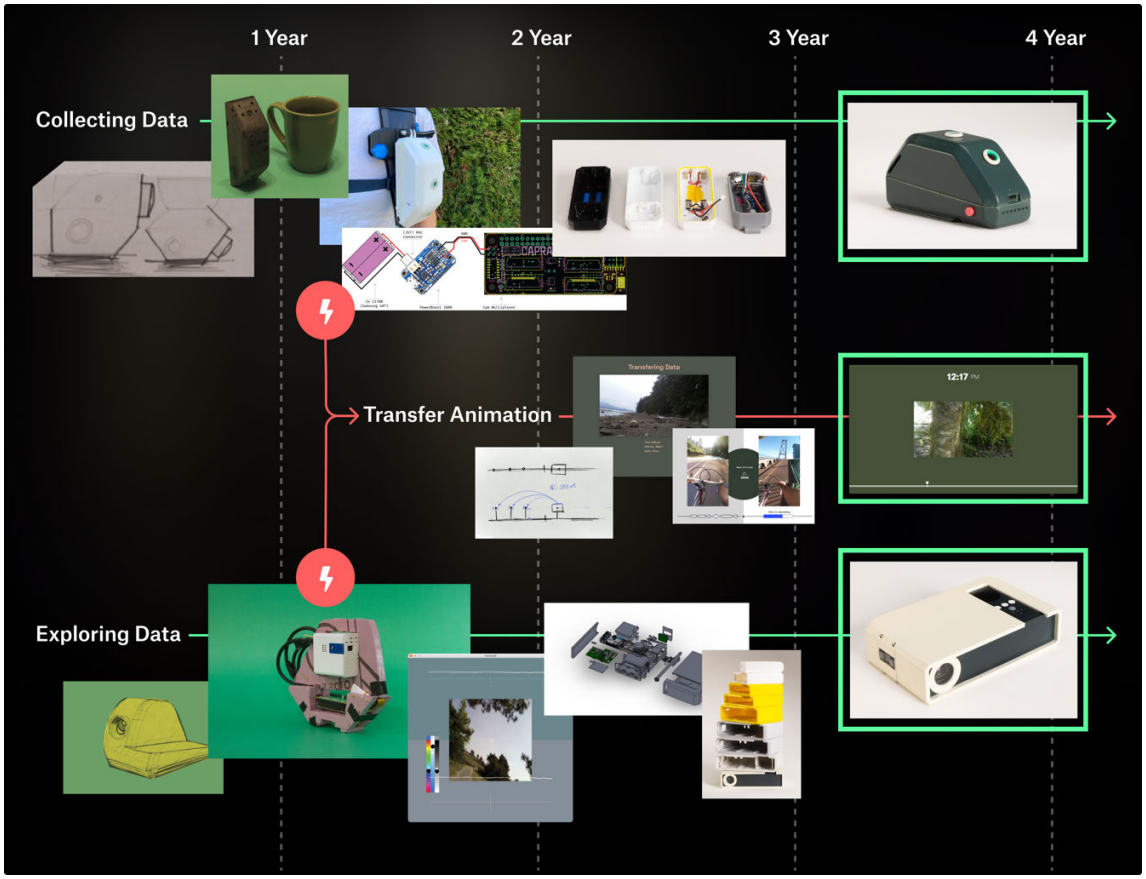

Figure 3: An abstracted and abbreviated visual representation of the parallel and intertwined development of the Capra Collector and Capra Explorer, through which hardware limitations and design frictions lead to the eventual emergence of the third thread which connected them, the Transfer Animation.

design process in light of our design theoretic framing and research questions. Following prior work mobilizing a designer-researcher approach, our approach to reporting the design research process is aligned with design journey narratives [23, 27, 53, 77]. Within 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.

The design of the Explorer and Collector emerged from a desire to create a fully enclosed system that enabled a hiker to have agency over the collection and exploration of their data, and thus were intrinsically intertwined and occurred simultaneously. The Collector is a wearable camera device equipped with three lenses (affixed at different angles) that captures Multi-Point-of-View time lapse photos during hiking sessions and encodes them with three forms of metadata: temporal (time of day), altitude, and dominant color. The Explorer is a device with an inbuilt projector for viewing and interacting with hiking data when desired; it has a book-like appearance and houses the repository of all hikes captured through the Collector. The temporal, altitude, and color metadata operate as filters that one can use to explore different ways of organizing and viewing their hiking data through manipulating a minimal set of controls on the Explorer. Importantly, these filters can be applied when exploring *a single hike* — offering different trajectories for moving through moments in a hike — or *across all hikes* — enabling explorations of various temporal, altitudinal, and color-oriented interconnections over time across all hiking data that has been captured.

As the two devices matured, hardware limitations and design frictions necessitated the intentional design of the transfer of data from the Collector to the Explorer, which became the Transfer Animation and a third distinct focus (see Figure 3). The transfer animation is triggered when the Collector is inserted into the Explorer. During periods of data transfer, the Explorer projects a changing sequence of images into the home that illustrate interconnections among moments in the new hiking data and the broader existing archive of hikes. To explain the design research process coherently, we separate these threads and pull on them in a linear fashion, beginning with how data is collected (4.1 Capra Collector), followed by its transfer (4.2 Capra Collector + Explorer: Transfer), and finally where it is explored (4.3 Capra Explorer).

Figure 4: From left: The Collector revealing the red power button and charging port; the Collector mounted on a backpack (via its compatibility with GoPro mounting hardware) and flashing a green light to indicate that it has started capturing images and metadata.

4.1 Capra Collector

4.1.1 Exploring Multiple Visual Perspectives through Lapse Photography: Revealing and Reflecting at the Seams. The Collector is a wearable camera device that can be easily attached and detached on one's backpack strap while hiking (Figure 4). When beginning a hike, the Collector can be turned on to start a recording. This recording continues throughout the hike unless it is paused. When the Collector is powered off at the end of a journey, the hike is saved locally. The Collector takes time-lapse photos — every 5 seconds a unit of three photos (one per camera) are captured. We were inspired by time-lapse and hyper-lapse documentary photography which aim to capture change over long time periods, often providing opportunities for noticing parts of the world that are difficult to recognize in the present (e.g., the subtle growth of a plant, movement of a glacier, changes over time along a familiar trail). In our view, the slow, dynamic qualities of noticing over time through lapse photography aligned well with Strauss and Fuad-Luke's Slow Design principles of *reveal* and *reflect* where "spaces and experiences in everyday life that are often missed or forgotten" can be expressed through an artifact's creation to "induce contemplation and 'reflective consumption"' [94].

We wanted to create an artifact that might contrast mainstream wearable action cameras through offering different ways of reviewing one's hike, yet which had a resolved and somewhat familiar look, feel, and aesthetic when worn on the body. Our aim was to divert from commercial products like GoPro and Insta360 cameras which emphasize the rapid editing of one's content, prioritize social sharing, and are significantly enhanced by proprietary software. We also wanted to contrast hiking data collection and use with outdoor recreation data sharing platforms, such as Strava [114] or FastestKnownTime [112], which emphasize quantified social comparisons of athletic performance. Our goal is not to disparage these technologies, but to reinforce our focus on extending into a different design space that emphasizes different trajectories of open-ended *exploration* of one's hiking data over longer time periods of use and non-use (i.e. *a lifetime*).

Through numerous iterations (see Figure 5), we eventually arrived at integrating three cameras as a cornerstone of the Collector design which, taken together, could capture multiple visual perspectives of each hike. Three cameras enabled us to record rich, at time unusual, visual perspectives and time lapse of hikes, while retaining a relatively unobtrusive form factor that was compact enough to avoid being too physically disruptive while hiking. In its final form, the Collector positions a central camera that faces forward to offer a more familiar 'point of view' (PoV), whereas the other two point upwards toward the sky and downwards towards the ground, which combine to form a 'Multi-PoV'. Although never applied in the context of capturing photos, prior design research has found that integrating a familiar lens or "intelligible baseline" [80:292] for people to engage in opened-ended explorations of their personal data can be an effective strategy that can be scaffolded to encourage engagement with more unfamiliar modalities that require interpretation over time. In our case, we found that central camera offered a recognizable PoV when worn on the body, that could offer a resource or bridge for shifting one's gaze to engage with phenomena captured on the other more unusual angles.

Importantly, due to the fixed camera angles, shifting environmental topography, and movement of the hiker, the three photos comprising the Multi-PoV do not necessarily seamlessly stitch together (although it is possible). In early field testing, we considered writing a script that would create more seamless juxtapositions — in a sense, stitching each three-photo Multi-PoV together into what could be considered a more visually unified and symmetrical portrait collage (see Figure 6). Yet, over time, we found the offset nature of the Multi-PoV captured through the Collector was highly generative in provoking reflections on what might exist 'in between' the seams. Equally, the offset quality and different gradations of color across the Multi-PoV portraits offered a polyphonic gaze that motivated us to attend to different elements of the outdoor places we moved through. For example, through contemplating ecologies existing within forests 15 meters above our own location on the trail, or shifts in root structures and sedimented patterns on rocks that passed underfoot. We found this design quality exhibited synergy with the slow design philosophy concept of *reveal and reflect* [94] as well as with Elsden's concept of *designing poetic data* [29:656] and calls to support open-ended data encounters [24, 80, 91]. These

Figure 5: Numerous iterations of the 3D printed Collector enclosure were required to integrate three cameras and their associated hardware and lenses into a resolved form that was both small and light enough to wear comfortably on a backpack strap, and robust enough to survive hiking in the wild.

emergent imperfections at the seams appeared, in part, to counter the precision or 'objectivity' of the data captured and to prompt interpretation as the subjective reconstructive process of remembering unfolded. This decision also builds on Chalmer's vision of *seamful design* in wearable technology where uncertainty arising from mobility can offer productive interpretive resources — "when such seams show through, as they inevitably do, users perceive and appropriate them for their own uses" [13:11].

Finally, we integrated a small socket at the top of the Collector enclosure to enable it to be easily attached and detached onto a backpack via a screw mount (see Figure 4). This decision enabled the hiker to fluidly move between capturing a *hyperlapse* (a time-series of moving photos when on one's body during a hike), and a *timelapse* (a time-series of photos where the location did not move, from a perspective beyond one's body). While a seemingly minor decision, as our process continued and we began to amass hikes, we found revisiting sequences that moved between a primarily human-centered perspective on the trail, to key moments of noticing elements within surroundings from a distinctly different perspective to evoke valuable moments of pause and reflection. This opened opportunities to consider slow pacing and to generate moments of dwelling with the re-visited hike. We often considered, reflected on, and discussed elements, ecologies, and temporalities bound up in the unique vantage points captured in these disembodied views, such as from a dry riverbed prior to the arrival of snowmelt or nestled in a mossy tree among branches, duff, dirt, mycelium and other things (see Figure 7). We found these records and oscillating paces of moving and dwelling in nature, often viewed through the Multi-PoV, prompted a certain kind of noticing and being more willing to, as Liu et al. articulate, "listen, observe, and respond to nature. . . and be vulnerable and amazed in the design process" [65:612]. The collective insights detailed here, in part, confirmed and validated the design direction of the Capra Collector.

4.1.2 Collecting the 'right' metadata for supporting open-ended revisitation of hiking experiences. The Collector also simultaneously captures and encodes three parallel sets of metadata within a photo each time one is taken: *the time of day* (timestamp), *the altitude*, and the *dominant colors* present in the photo. Building on recent research that has illustrated the rich reflective potentialities that metadata can offer when combined with personal media (e.g., [18, 29, 42, 51, 80]), our intention was to capture a set of hiking metadata to work with as design resources for supporting open-ended interactions in and across hikes as they are retrospectively revisited with the Explorer. We initially considered other types of hiking metadata, such as GPS location (from which we could infer pace and distance), heartrate, and orientation, but ultimately decided to omit them from the final design. On a practical level, GPS and a 3D compass were too costly in terms of battery life, and a heartrate sensor was too obtrusive. On a conceptual level, our

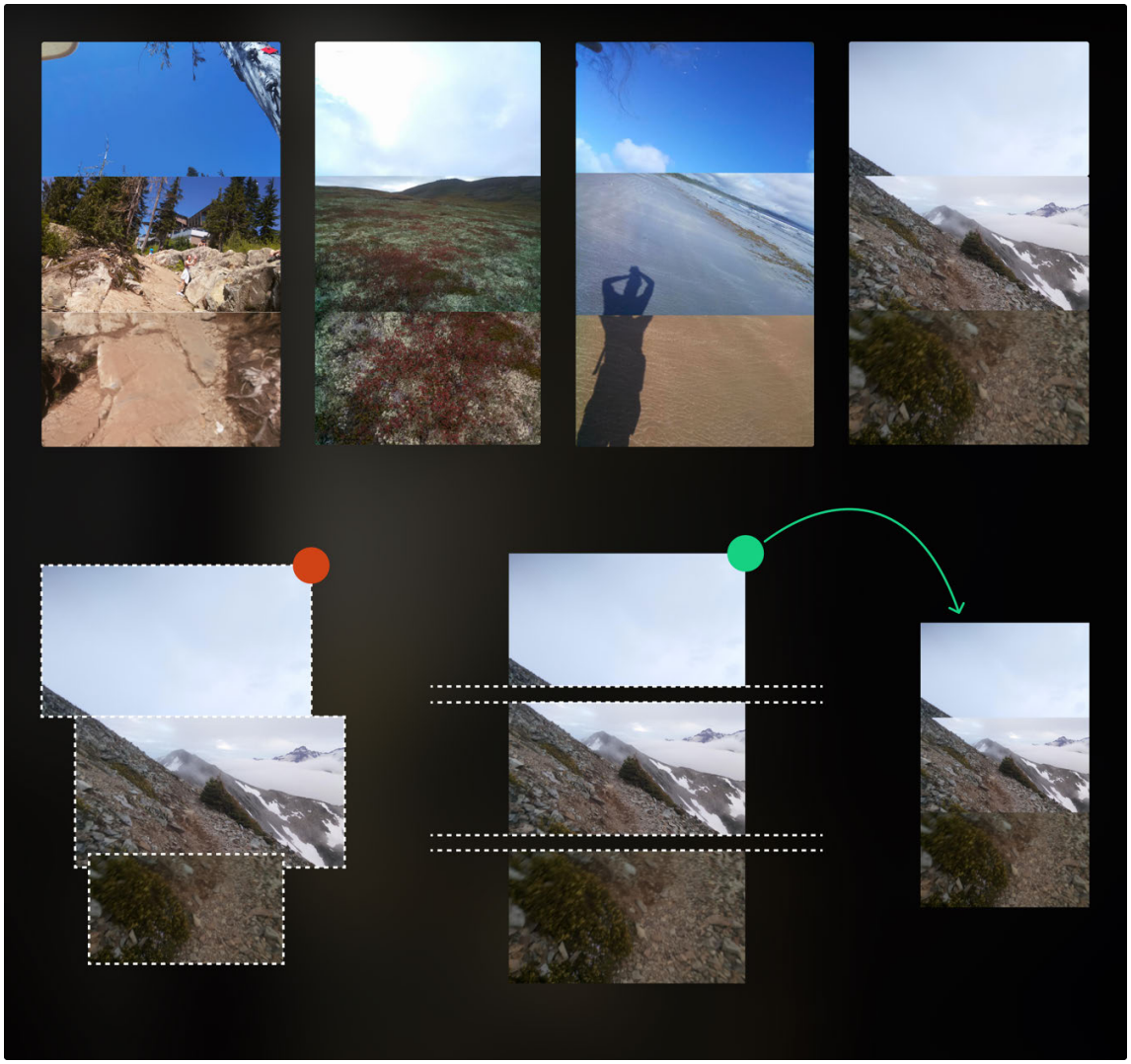

Figure 6: The Collector captures images from three different perspectives — offset on the vertical axis far enough that there is a slight gap between each lens's field of view. We explored different ways of stitching these images back together: through connecting visual features; treating them as separate images; before ultimately stacking them and embracing the seams that this emphasizes.

early design experiments revealed these forms of metadata tended to yield concepts that were more quantitative and goal-oriented which did not a fit well with our research aims. We were able to easily capture timestamps, altitude, and dominant colors in reliable and computationally inexpensive ways. Conceptually, we found these three forms of metadata could lead to a range of potential experiences. For example, exploring where in nature one has dwelled during different periods of the day (or night), changes in the environment across altitudinal contours, or shifts in color across locations, seasons, or perhaps even garments worn by hiking companions (we elaborate on our process in working with these metadata in section 4.3).

4.1.3 Grappling with Unobtrusiveness: Conceptual Goals Meet Technical Precarities. Our process of creating the Collector centered on the need for *unobtrusiveness* to take primary consideration when designing the form, implementation, and interaction to "avoid human-nature disruption" [43:7]. With this in mind, we had designed the Collector to signal different system states (e.g., when it was on, capturing data, paused, or powering down) through a minimal set of colored lights tucked into a small notch on the enclosure (See Figure 1). Other than this feedback — which was largely out of sight unless intentionally viewed by the hiker — the Collector silently and perpetually captured photos and data, largely fading into the background out of direct 'use' while on the trail. While this highly minimal interaction design appeared to partially satisfy our goal for unobtrusiveness, the form and implementation presented a key friction. It became apparent that all of the Collector's electronic components would need to be integrated in a small contained wearable form factor to avoid it being too physically disruptive and

Figure 7: The Collector is easily detached from its mounting point, so that it can shift from capturing hyperlapses to timelapses and thus encode other than human perspectives within the hiking data.

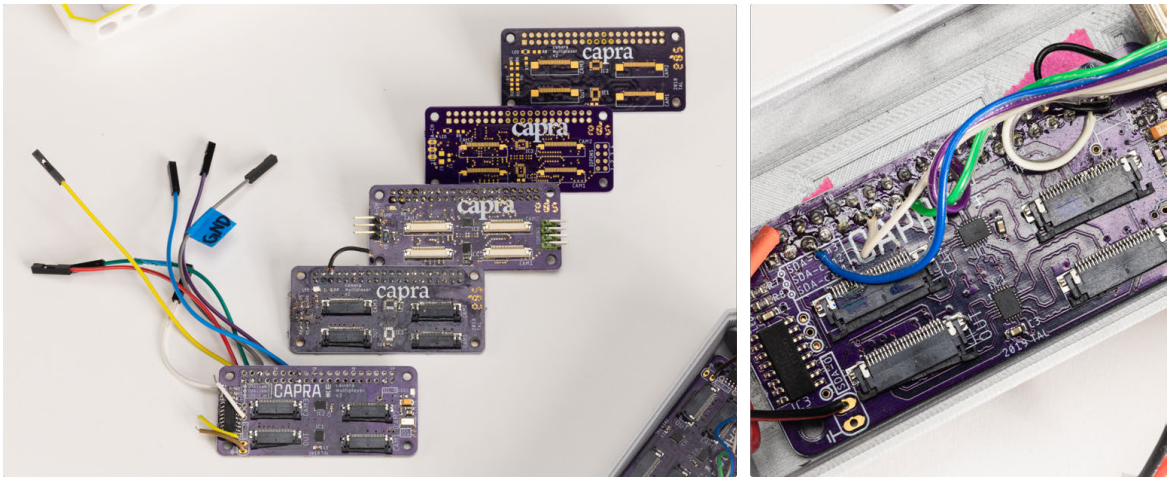

Figure 8: Iterations of the 30mm x 70mm sized Cam Multiplexer PCB that we engineered to support the design requirements.

mentally attention grabbing while worn. Satisfying this dimension of unobtrusiveness turned out to be a substantial undertaking. The Raspberry Pi Zero (RP zero) offered a small (65mm x 30mm), robust, and powerful single board computer, yet it was only capable of connecting to a single camera. At the time (and still now at the writing of this paper), there were no known commercially available circuit boards that could integrate numerous cameras to a RP zero (no less at a small form factor). The core challenge is that three cameras needed to be multiplexed into the single Camera Serial Interface (CSI) camera port on the RP zero; thus we had to invent a robust and reliable way of switching among each camera and transmitting the data back to the RP zero. Through an iterative process that unfolded over 11 months, we eventually engineered and manufactured a novel 30mm x 70mm sized Cam Multiplexer Printed Circuit Board (PCB) that provided a solution with a single analog multiplexer chip that controlled two low power high-speed Mobile Industry Processor Interface (MIPIP) switches. This PCB fits directly on top of the RP zero and enables it to switch among cameras while taking photos (see Figure 8 for iterations). We integrated a MPL3115A2 Altimeter on this board for altitude sensing and included a DS3231 Real Time Clock (RTC) to keep the RP zero's internal clock synchronized. Typically, an RP zero sets its time on boot by querying an online time server via an internet connection (which is not always possible or desirable while hiking). The RTC continues to keep the time for the RP zero even when it is powered off, which will last for approximately one decade on its coin cell battery before requiring replacement. The Collector uses two rechargeable 21700 LiPo batteries which can power the system for roughly 10 hours of use. We also designed a custom PCB to support interactions with buttons on the Collector for powering it on and off, and for pausing the recording. We resolved the Collector's form through numerous iterations to account for structural robustness, waterproofing, and finishing. The final form is 3D printed out of ABS, and then airbrushed in hunter green paint with the external camera lenses fitted within cream-colored sockets that affix waterproofed ultra-violet protected lenses atop them.

4.2 Capra Collector + Explorer: Transfer

4.2.1 Making Space for Pre-Interaction as Data Moves from the Collector to Explorer. The extended time required to create a durable, robust Capra Collector for long-term use also created an unexpected

Figure 9: The Collector slides into the Explorer and renders the control interface inaccessible.

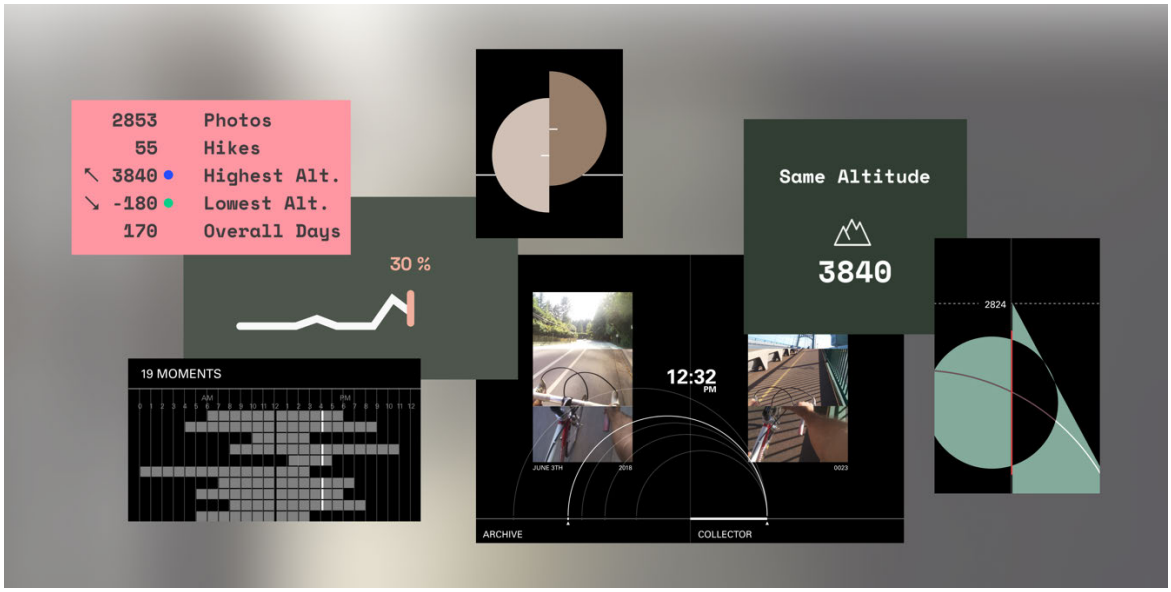

Figure 10: A selection of our design exploration for the Transfer Animation that ranged from too quantified to too abstract in their representations of how new data relates to the archive.

opportunity for pause and reflection in our process. Through iteratively testing the Collector, we logged hiking data and began to explore relations among different hikes as well as the three forms of metadata. While we had always envisioned the Explorer as the site for *interacting* with hiking data, it became apparent that the transfer process between the Collector and the Explorer represented a key overlooked touchpoint. Due to waterproofing, once the Collector was fully operational, tested, and sealed, it was impractical to frequently re-open the enclosure. Therefore, it was not viable to transmit data via a memory card. Instead, we opted to use a local WiFi network (disconnected from the internet) for data transmission. Since a single hike generally results in thousands of images, the transfer time could last hours (e.g., in our experience this process typically took 1–4 hours per hike).

This temporal duration made us reflect on the act of returning home and how one's data might 'settle in' to the existing archive of hikes as they accumulate. We were inspired by the *pre-interaction* design quality which has been mobilized as a technique to prime slow, reflective experiences with personal data outside of direct interaction (e.g., [78]). We redesigned the Explorer's form to include a beveled edge above the tangible controls for interaction; the data transfer begins when the Collector tightly slides into this location — effectively covering the controls entirely as a subtle cue toward pre-interaction and explicit slowness — the user cannot speed up or modulate the transfer process nor the slowly changing projections that temporality become present in the home (see Figure 9).

4.2.2 Iterating through Design Alternatives for the Transfer: From Quantified Comparisons to Open-ended Interconnections. The need for the Transfer Animation emerged initially as a hardware limitation and was implemented in the same codebase that handles the processing of data as it is transferred. As we began our design

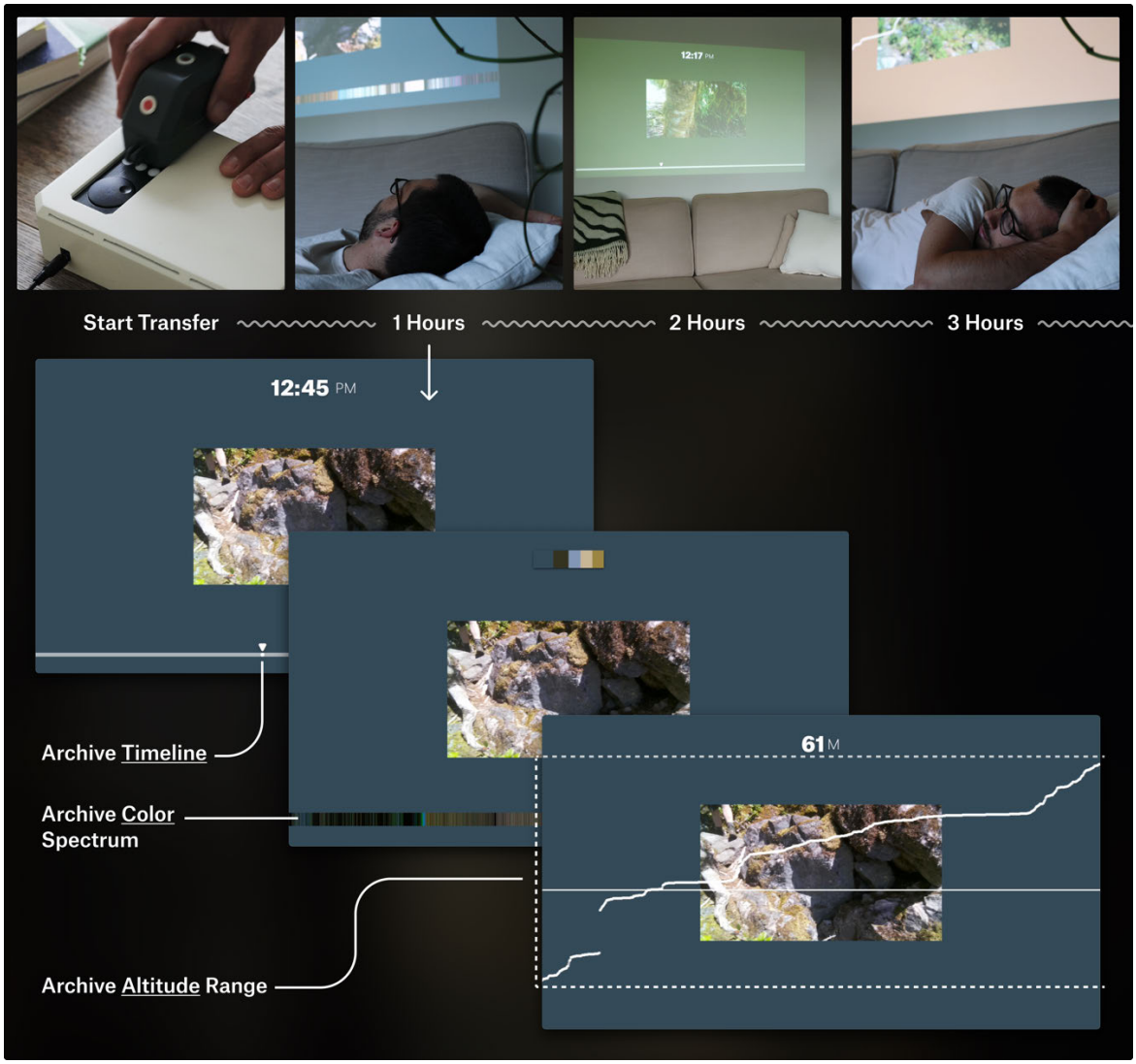

Figure 11: The Transfer Animation is initiated when the Collector with hikes stored locally, is slid into the Explorer. As images are transferred, the three metadata filters are cycled through as overlays that subtly compare the current image with all others in the hiking archive: the time is situated within the timescale of a day; the color is connected to the full spectrum of colors in the archive; and the altitude is represented as a line through the range of collected altitudes. The background is the image's dominant color.

exploration for the Transfer Animation, we were immediately able to understand how each new image related to entire archive as it transfers to the Explorer, and we were excited by the richness of these connections. This led our initial design alternatives focusing on finite relationships between images and trending too far towards quantified comparisons and (see examples in Figure 10). We found this complicated our goals of more interpretative open-ended priming of interconnections among elements in the archive. Our reactionary designs were so abstract that they were also unsuccessful in prompting reflection on the data, in this case because it was not possible to interpret any potential relationships with the archive. Ultimately, we moved toward a more minimal and understated design for the Transfer Animation, in which each image is shown as it is transferred with an overlay indicating where it lands in the archive through each of its metadata filters (see Figure 11).

On a technical level, as data is transferred, the Explorer creates the multi-PoV composite images from each cycle of three photos and integrates each composite photo (and attendant metadata) within a relational database during transfer. While this occurs, slowly changing images are projected into the home which illustrate relationships among photos from the new hike (or hikes) and the archive, through the filters of time, color, and altitude (see Figure 11). The image is situated in the context of all other images taken

Figure 12: The Capra Explorer is roughly the size of a medium-sized hardcover book. It stores the archive of images and metadata, is the site of interaction and exploration, and projects onto a wall in the user's home.

at that time of day; its dominant colors are extracted and shown in the context of the full spectrum of colors within the archive; and its altitude is juxtaposed along a rising visual continuum indicating its 'height' in relation to the entire archive. We aimed for these design decisions to allude to possible chronological and non-linear forms of *temporal interconnectedness* among different moments in the recent hikes being transmitted as well as among the numerous hikes stored in the Explorer archive. Upon the successful conclusion of the transmission, all hiking data now stored on the Explorer will be deleted from the Collector, and both devices can be shutdown.

4.3 Capra Explorer

The Explorer is the site where hiking data is stored, interconnected, and interacted with. The final research product is embodied in a weighty book-like enclosure (see Figure 12). It enables a person to re-explore moments of either *a single hike* or *across all of their hikes* through multiple visual perspectives and metadata-enabled filters of *time*, *altitude*, and *color*. Yet, arriving at this final form was not a straight path and involved navigating several frictions bound to designing for occasional, yet long term open-ended interactions that scale as one's hiking archive — and one's relation to hiking as a practice — evolve over time. Next, we detail numerous frictions that prompted us to make critical design decisions to resolve them in light of our higher-level conceptual goals and research questions. Next, we turn to how we worked with our hiking metadata as design materials.

4.3.1 Form Giving and Iterative Exploration. Early in our process we arrived at *time*, *color*, and *altitude* as three forms of metadata that we could reliably capture with the Collector and that appeared to have potential for supporting alternative perspectives on hikes that had been recorded. During this time, we began to accumulate numerous hikes among our design team as we field tested the Collector for functionality and durability. We were able systematically store and partition the collected hikes in a relational database, yet, in this form, all time, color, and altitude metadata were represented as numerical values (see Figure 13). This lack of presence and expressivity made it challenging to 'see' how we might balance integrating different filters within an interaction design that could provide context for interpretation and exploration while also not disrupting or overshadowing the hiking timelapses. We found no known ready-made tools existed to support such explorations. This friction motivated us to iteratively develop a series of plug-ins for the design application Sketch to enable rapid, creative explorations (see Figure 14).

For example, with altitude we were able to copy a series of data (e.g., from an entire hike or a specific portion) and our Sketch plugin would complete the calculations to show the altitudinal curve of the hike, which we could further manipulate and refine. This demonstrated that our approach could work, and it also revealed unanticipated issues. For example, with color metadata, the Sketch prototype showed that while a granularity of 1280 different colors was achievable, it was also nearly unintelligible and disruptive when viewed in a single hike. We were able to rapidly re-size and re-adjust the parsing of the color metadata and iteratively settle on using 128 colors, which struck a balance between offering enough fidelity to be 'readable' but not overwhelming (see Figure 14 for an example). These plug-ins were vital in showing us what the

	time	altitude	hike	index_in_hike
286	1593974458	913.89	3	271
287	1593974463	914.89	3	272
288	1593974468	915.58	3	273

Figure 13: An excerpt from the Explorer SQLite database showing how metadata is stored.

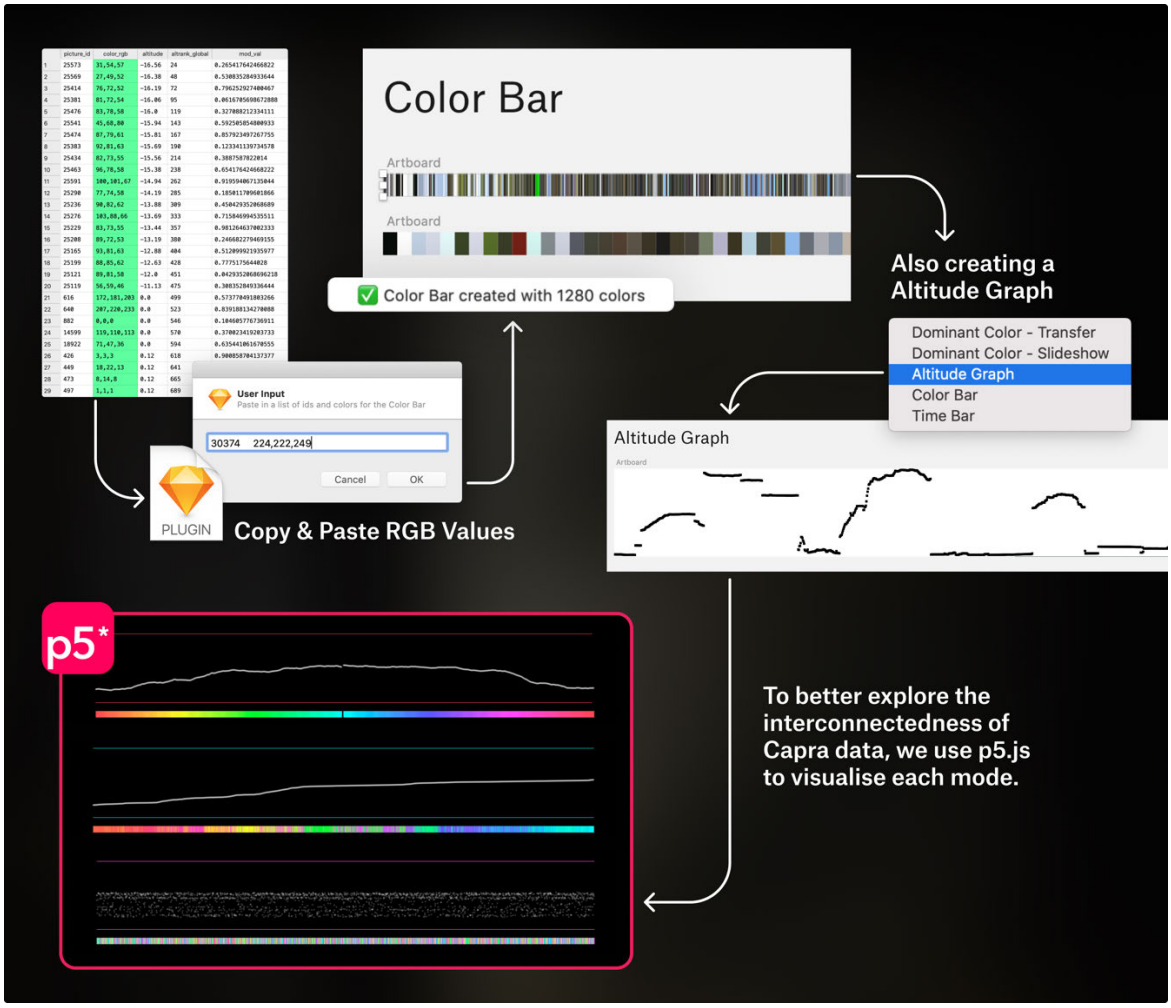

Figure 14: Sketch plugins and p5.js sketches that allowed us to understand and design with data.

actual data could look like, and in supporting rapid design iterations through potential ways of representing it. Yet, a key limitation with this workflow was that we developed individual prototype plug-ins for each form of metadata and thus we could not view potential interconnections across them.

As we shaped our understanding of how the individual filters could be represented, we used the creative coding library p5.js to develop interactive sketches that could sort and resort placeholder data, to learn about how these different data representations might work in unison. With these sketches we could explore how each of the representations might look, when the data was sorted by a different filter (i.e., what would happen to the altitude visualization, when the data was sorted by time or color). These explorations demonstrated that there was richness in our design direction, but the placeholder data limited our ability to assess its emotive quality.

In the subsequent phase of our process, we began to creatively apply these lessons learned through building a working Python application that integrated all three metadata design elements simultaneously within dynamic lapses of our hikes. As this prototype took form, we began noticing intriguing interrelations emerging among hiking data and that these instances could prompt memories as well as interpretive and anticipatory encounters. Consider the example in Figure 15 below, where Jordan reflects on an early working prototype of the Explorer software, in one instance where we had juxtaposed dominant colors of the hike along with the timeline of the hike; and in another where altitude played a significant role.

Collectively, through these formative experiences we were able to develop workarounds to get a grasp on our hiking metadata as expressive and reflective materials for design. We were able to progressively move towards early working prototypes that further validated the potentiality of how these forms of metadata might operate as rich resources for interpreting, anticipating, and exploring memories and associations bound up in hikes we had recorded while field testing the Collector.

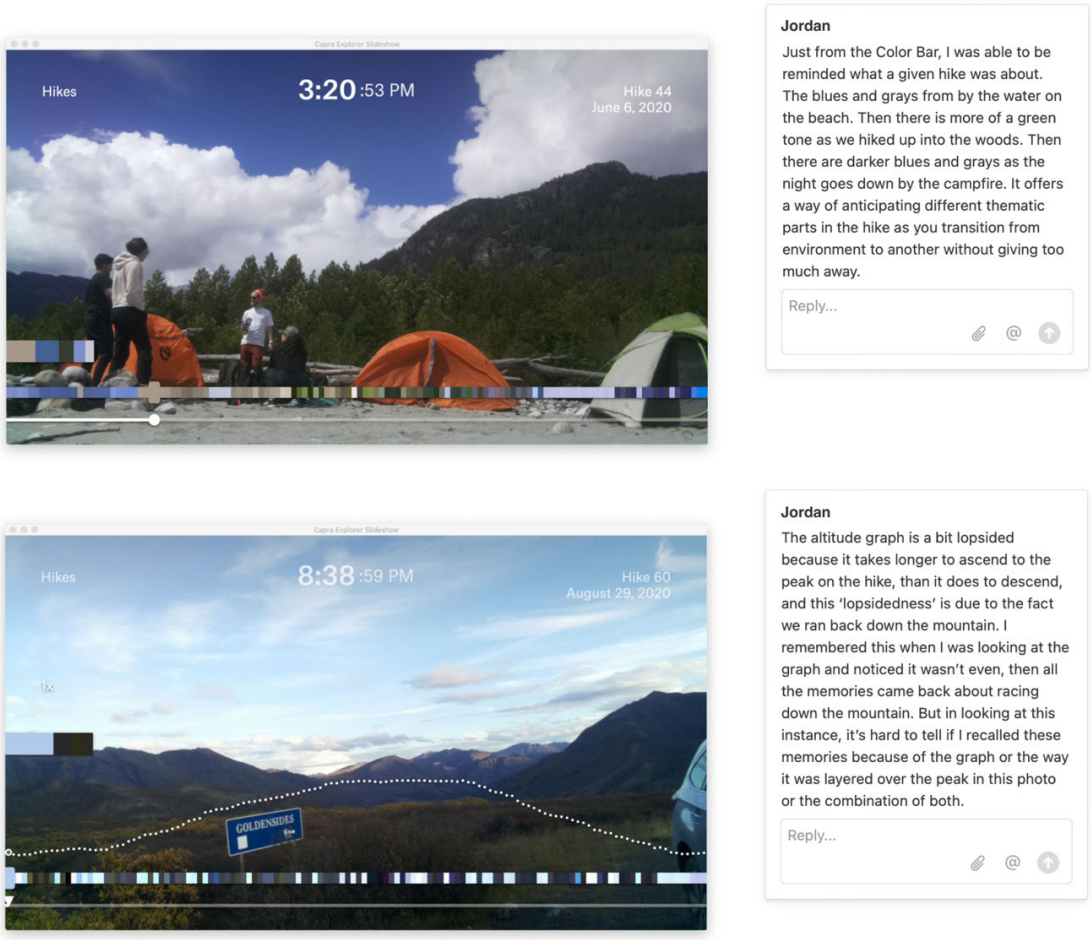

Figure 15: A screenshot from our shared Notion workspace where Jordan reflects on how with a Collector prototype, seeing the overlay of time and color shaped their re-experience of a hike, and how the altitude overlay operated as a resource for remembering as it blended with the photographic imagery.

4.3.2 Crafting Different Perspectives: Arriving at 3 Filters & 2 Modes. From early in our design process, we were interested in being able to explore the hiking data *in individual hikes* (Hike mode) as well as *across all hikes in their entirety* (Archive mode). The ability to fluidly shift between the Hike and Archive modes is a cornerstone of the Explorer interaction design; to explain the interactive connection between these two modes, consider the following scenarios. As an individual hike is being revisited (in Hike mode) the user can opt to shift to Archive mode at any time, effectively taking that precise moment in time, altitude, or color in the individual hike they were exploring and relationally resituating it into the place it fits among all hikes; the timelapse continues to unfold from there without missing a step. For example, if one was exploring a particularly appealing set of blue colors from a recent glacial hike (in Hike mode), Archive mode could be enabled to 'locate' and begin moving through the most related set of colors in spectrum across all hikes recorded (e.g., perhaps a similar set of blue skies, glacial water, or blue raincoats that were captured on past hikes might emerge). If left untouched, eventually the Explorer would slowly progress to another color in the spectrum, and so on. Equally, if one is traversing through all hikes (in Archive mode) as they reexplored steps taken on trails in the early morning around 5:30am and a hiking companion appears that momentarily conjures a murky memory from some years back, they could then shift to Hike mode to jump into the specific time and place of that hike. Inspired by the design quality of *implicit slowness*, we felt this range in granularity could support conscious exploration of a specific hike in the past as well as interpretive consideration of known, partially known, or unknown connections across all hiking experiences that in ways that scale and change over time. Additionally, we found each of the metadata filters could yield different kinds of perspectives and pathways for each mode. Below we unpack the permutations of how the metadata filters (*time of day*, *color*, and *altitude*) scale across the scopes of *Hike mode* and *Archive mode* in the resolved Explorer research product.

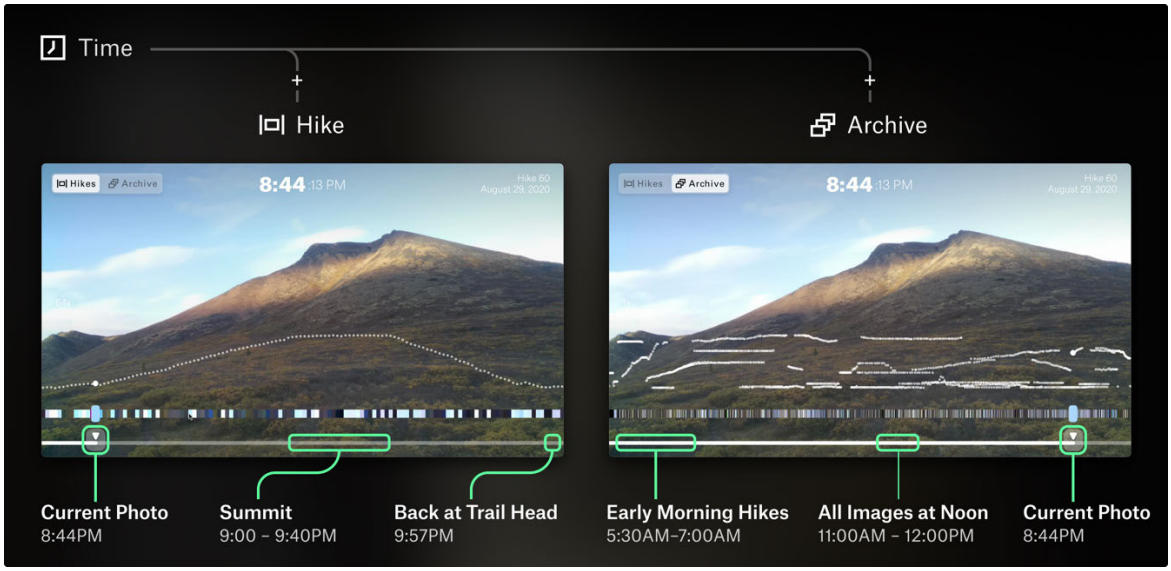

Figure 16: The UI of the Collector showing the *Time* filter in both *Hike* and *Archive* mode.

Time enables a chronological way of exploring one's journey on the trail (see Figure 16). In *Hike* mode it offers a familiar, sequential account of your hike, whereas in *Archive* mode *Time* can enable a user to explore and compare different places they have hiked at different times of the day, potentially noticing themes or differences in sunlight, location, or place. For example, if set to 5:30am in Archive mode, a durational trajectory of photos across all of one's early morning hikes that is closest to 5:30:00, 5:30:01, etc. will be shown (if left untouched, the Explorer will continue cycling through all hiking data in this sequence). Figure 16 illustrates that in hike mode, the time filter organizes this hike sequentially as it was hiked from the beginning to the end (at this point, we are at around 8:44pm); in archive mode, we can see that this specific moment from this specific hike exists as one of the later-in-the-day hikes; the next photo in the time lapse sequence will be pulled from the next 'latest' moment across all hikes, and so on).

Altitude enables a way of understanding the relative height that one travels across while hiking. In *Hike* mode, this means that a single hike will be durationally represented from the lowest to highest point. In *Archive* mode, this can allow the user to explore connections through different altitude levels across time. For example, one might explore comparative similarities or differences in

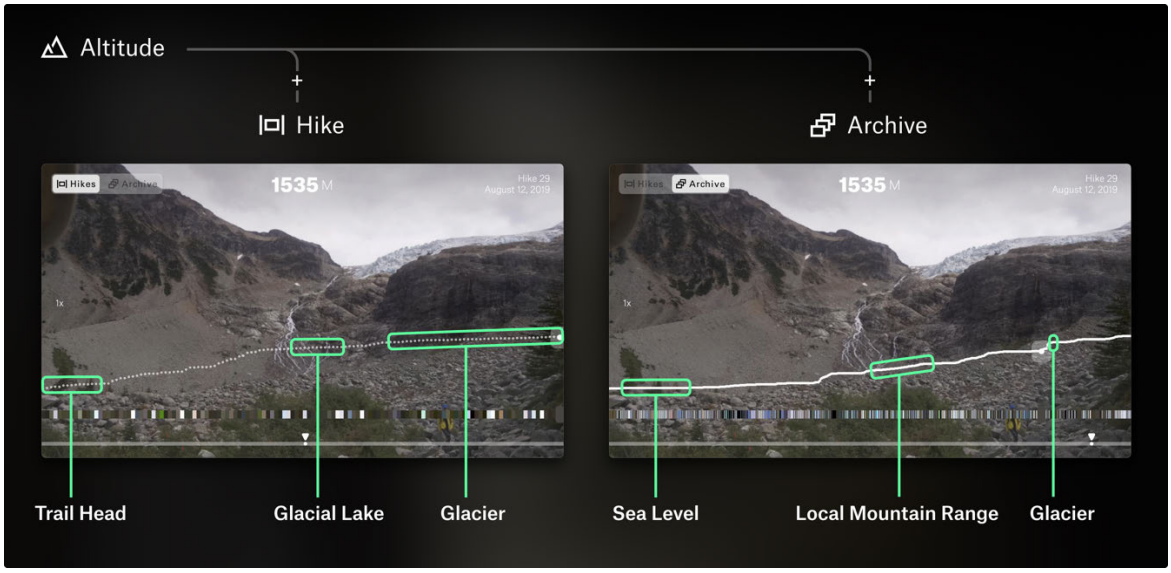

Figure 17: The UI of the Collector showing the *Altitude* filter in both *Hike* and *Archive* mode.

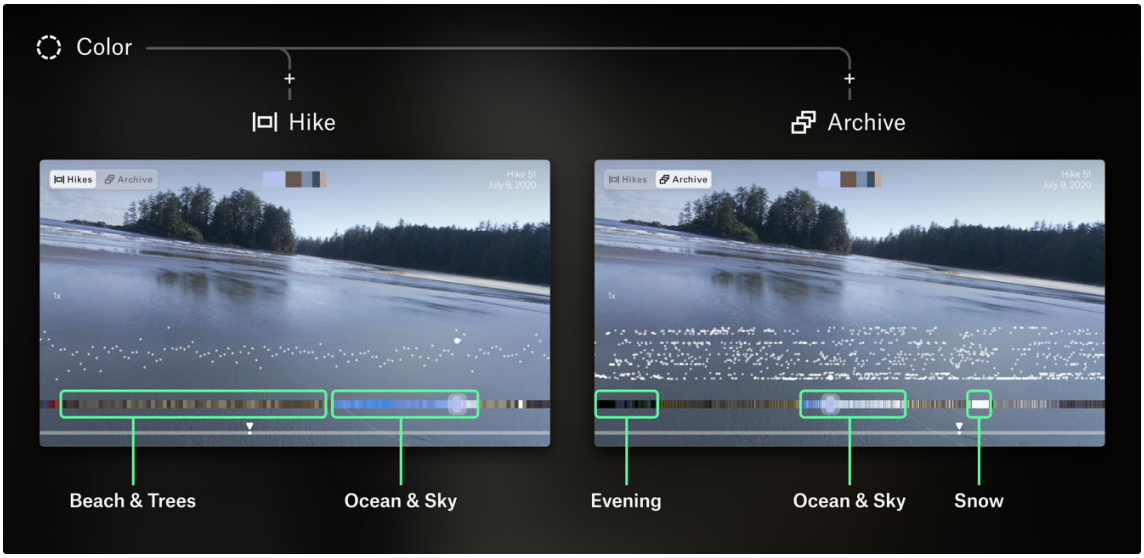

Figure 18: The UI of the Collector showing the *Color* filter in both *Hike* and *Archive* mode.

ecologies (or hiking companions) at various altitudes. Revisiting one's hiking data from the lowest altitude value in Archive mode will enable the user to slowly traverse from the 'lowest step' taken while hiking to the highest one, likely cross-cutting many associations, memories, and experiences while also potentially forming new interconnections among them. Figure 17 shows that in hike mode the durational time lapse of the journey is reorganized from the lowest point, at the trail head, to the highest point at the glacier. In archive mode, this specific moment in this specific hike is placed relatively high along the altitude arc of all hikes in the archive (i.e., the next 'highest step' on this journey as re-experienced through the Explorer may or may not be from this specific hike but will be at around this same altitude).

Color enables a more impressionistic, non-chronological way of revisiting one's hikes. In *Hike* mode, each hike will be shown through the aggregation of most occurring color depicted in each photo. In *Archive* mode, large swatches of color are grouped together across all hikes, potentially provoking consideration of interconnected elements across seasons, locations, or visual changes in topography. For example, one might navigate to bright orange and red hues to locate sunrises, sunsets, or autumn leaves or to vibrant blue hues to locate clear skies, glacial lakes, the parka of a hiking companion, and perhaps some Stellar's Jays. As seen in Figure 18, in Hike mode the hike is separated between the portion that traversed across the beach and through a forest, and the section on wet sand looking out at blue skies. In Archive mode, this blue section remains prominent.

4.3.3 Supporting Open-Ended Interactions through Evolving Interconnections. Importantly, as these journeys unfold through time-lapses, the interaction design remains open and dynamic. If the user decides to shift between modes or filters, the specific moment captured in the photo acts as the anchor point for determining the next pathway in the archive of hiking data (see Figure 19 below). For example, if one is in Hike mode with the Time filter engaged, viewing a mountainside journey on a brisk afternoon at 3:31:01pm, and they shift the mode to Archive, then the next 'closest' moment in the archive to 3:31:01pm will be displayed and the journey continues from there. If they had instead selected the Color filter (and remained in Hike mode), then all photos from the hike would be reorganized around where that precise moment fits in the color spectrum for that hike, and so on. In this way, the Explorer's interaction design is indeterminate; the user is not required to explore in any particular direction, nor through any filter. Interconnections among all hikes continue to evolve as the user gradually accumulates and integrates new hiking data in the Explorer archive.

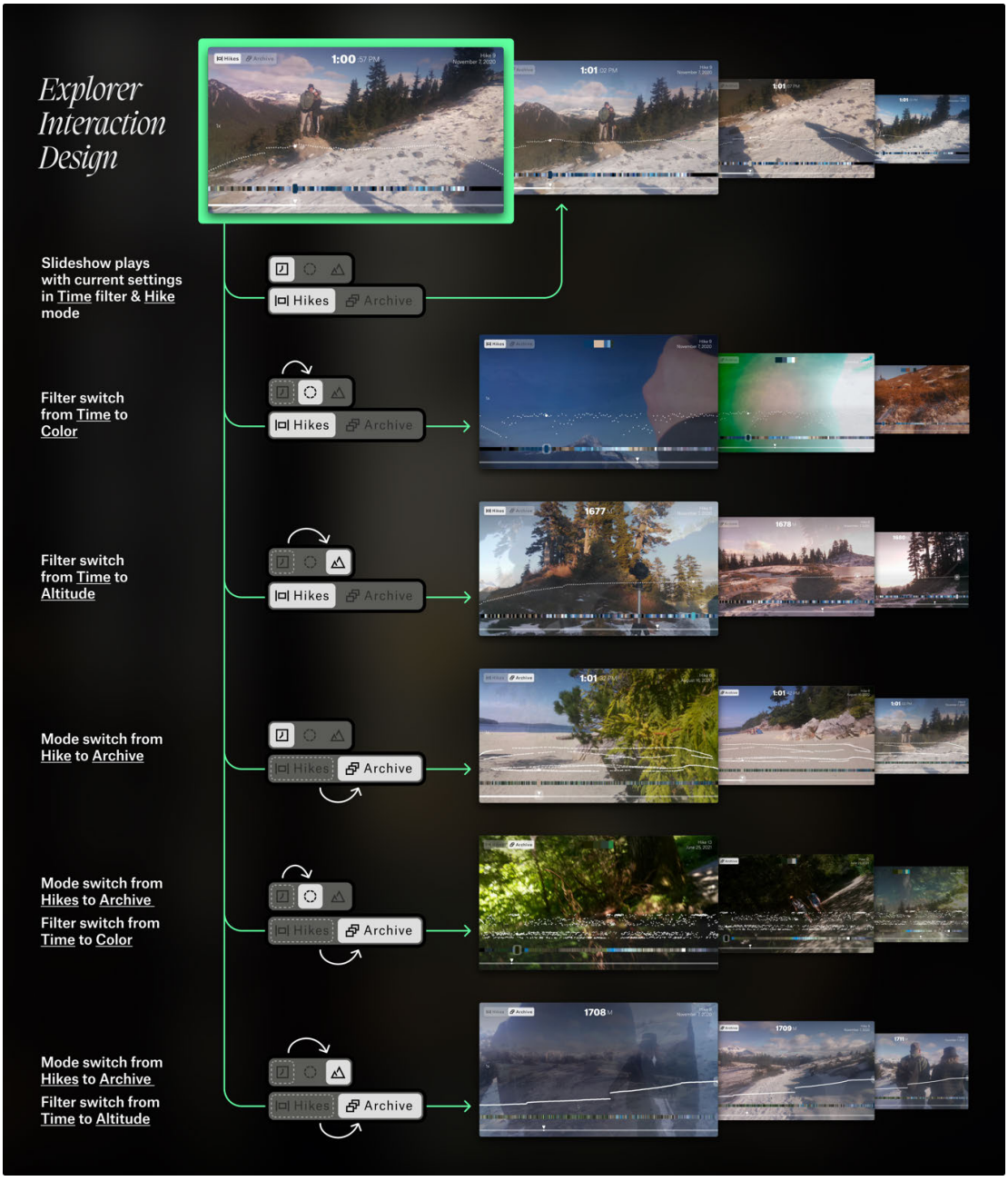

Figure 19: A diagram of the possible next 'steps' in or across hikes that a user may experience, depending on how they chose to interact with the Explorer as the durational time lapse proceeds ahead.

4.3.4 Explaining and Illustrating the Resolved Form and Interactions of the Capra Explorer. The final form of the Explorer aims to be open to interactions as intentional events and manipulations when in direct use, as well as piecemeal reconfigurations among other things in the home. We carefully considered its form for occasional interaction over a long time scale (e.g., when there may be periods of non-use or when it becomes integrated into different domestic environments over life changes and stages). The Explorer's weighty, book-like presence enables it to be stored or used in both horizontal and vertical orientations. This decision is, in part, aimed to create an artifact that could operate any multiple orientations, which we anticipated would open it up to other objects being situated on or around it over time. These concerns also motivated our decision to integrate a projector as the means for making hiking data present (and absent) in the home — a light projection can galvanize focused exploration through direct interaction, create an ambient backdrop when not in direct use, and subtly fade from view entirely when in non-use.

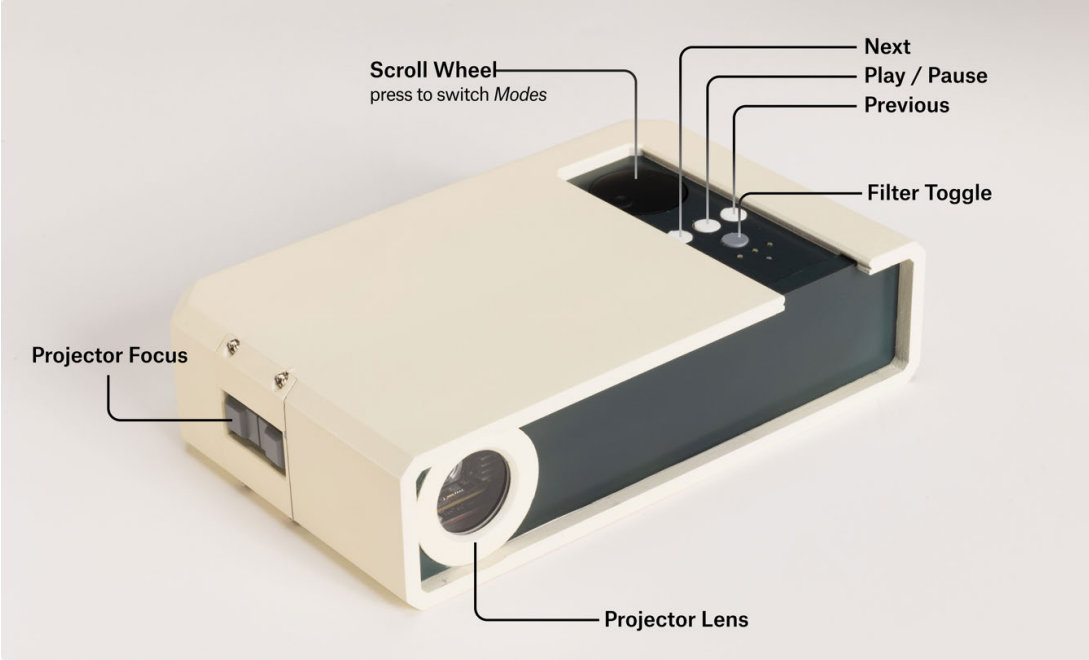

Figure 20: The final form of the Explorer is 3D printed out of ABS, and then airbrushed in cream with hunter green accents. The external projector lens is also fitted with a cream-colored socket as a subtle reference to the Collector's lenses. A minimal set of tangible controls enables one to move among various modes and filters enabled by the Explorer; these controls are available when the Explorer is in either a horizontal or vertical orientation.

When in use, the orientation of the Explorer form factor dictates what is projected. When horizontal (lying flat), it projects the central PoV perspective photo sequence accompanied by a brief overlay of the metadata based on the selected filter (with the metadata overlay fading away after 3 seconds if no tangible controls are manipulated). When rotated and placed vertical, the Multi-PoV timelapse is shown without overlay to emphasize the noticing and exploration of the sequence. Both perspectives can easily be toggled between through manipulating the Explorer form (see Figure 21).

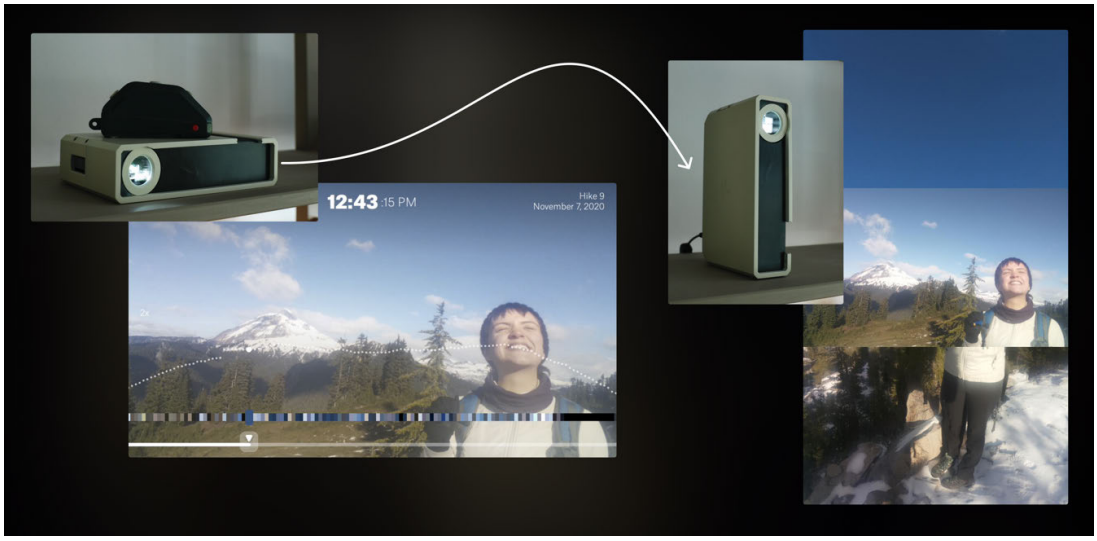

Figure 21: The accelerometer within the Explorer identifies when it is rotated between its horizontal and vertical orientations, and switches between the two projected UI states. When in horizontal mode only the eye-level PoV image is displayed, while in vertical mode the additional screen height is optimal to display all three PoVs.

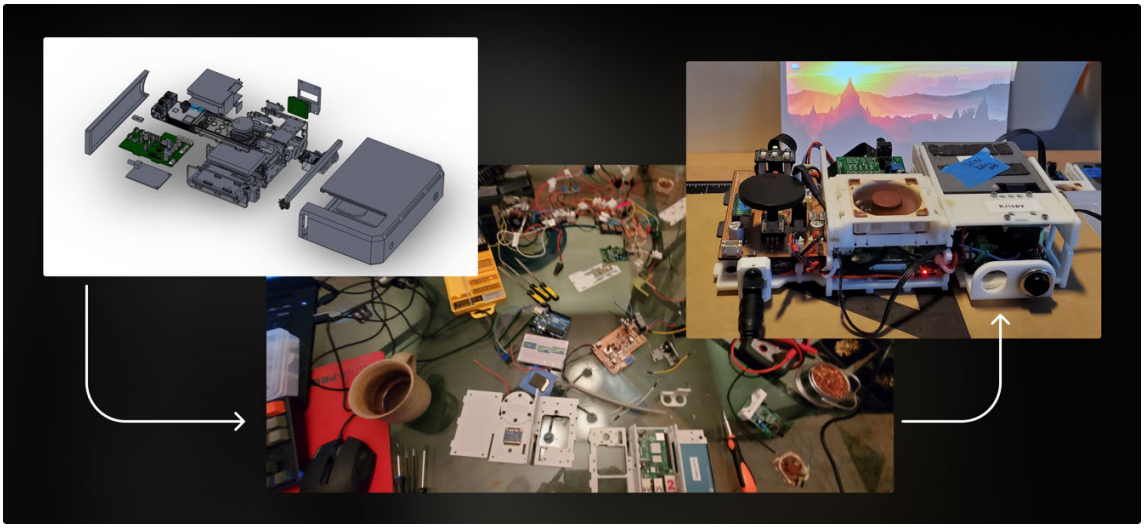

Figure 22: ***(left)*** **Exploded CAD illustration of the Explorer showing some internal components.** ***(center)*** **In progress assembly of the Explorer with our custom PCB.** ***(right)*** **Collector unit test before being sealed in the enclosure.**

4.3.5 Reflecting on Temporal Matters, Technical Precarities & Trade-offs with the Explorer. As we moved from Sketch prototypes to building a working prototype that integrated all three real forms of metadata with lapse photography captured through the Collector, we committed to implementing the Explorer in the Python programming language on the Raspberry Pi 4. This decision came after considerable discussion and critical reflection among our team. Python provided an environment that was native to the Raspberry Pi, allowing us to integrate a small, yet powerful computer to drive the Explorer while retaining a relatively small overall form factor. This was important because it allowed us a design a form for the Explorer that could be of a proximal size in relation to the Collector, enabling them to come together as an integrated whole during the transfer phase and, more broadly, as single system united through two devices.

Yet, this decision led to new challenges as Python has limited user interface (UI) libraries, making it initially difficult to achieve polish and consistency in the UI. Eventually, we arrived at using PyQt which required extensive development work to generate multiple overlapping layers, update metadata overlays in real time, and ensure a consistent durational flow of lapse photographs across the thousands of images that comprised each hike, and to anticipate accounting for the tens, if not, hundreds of thousands of images that would be in the entire hiking archive as it continued to grow.

When designing the software architecture of the Explorer, we knew that the level of image manipulation, data processing and extracting required would push the limits of the hardware. We considered offloading this computing task to an external server, and we also considered moving the entire hiking database to an external server and running the Explorer as an internet-connected web application — decisions that would have supported a more efficient and simpler development cycle. Yet, a core conceptual aim of Capra is to be a system that one may interact with occasionally in an ongoing way as hikes are accumulated over the years. Requiring an internet connection and a reliance on external servers, offered no promise of longevity and was directly at odds with our conceptual goals.

We created a custom PCB to allow for strategic placement of all peripheral components, accelerometer, LEDs, and power rails, which operated as an interface among a Raspberry Pi 4, motor driver (for adjusting the projector's focus), the projector, relay, fans, and the physical buttons. While the PCB is directly connected to the Raspberry Pi, all other components are connected to our custom PCB through JST-PH connectors. These decisions allowed us to make the Explorer system not only robust, but also modular where components can be removed, repaired, and replaced if necessary to ensure Capra can hold up over a long time period.

5 DISCUSSION AND IMPLICATIONS

As the practice of hiking is increasingly entangled with data driven applications and devices, new possibilities are emerging for people to generate digital records of their experiences outdoors. With this shift come concerns about potential disruptive consequences that might arise from technology on the trail. Yet, researchers also speculate that there is value in revisiting digital histories of one's journeys outdoors as they accumulate over time. Developing approaches to enable data to operate as a rich resource for noticing, remembering, and exploring one's evolving relationship to hiking in nature, while balancing the need for unobtrusiveness and agency when collecting data, presents important opportunities for the HCI community. This research territory also provokes new considerations for HCI about conceptually and practically engaging design spaces which encompass human-technology relations that scale and change over longer time periods, alongside lifelong practices, such as hiking. Through critically reflecting on our designer-researcher approach in creating Capra, we highlight opportunities and challenges that come with this emerging space for future research and practice.

5.1 The Collector: Working With Unobtrusiveness in Concept and Practice

Prior research has argued that unobtrusiveness [5, 43] must take primacy when designing technologies that mediate experiences in nature. Yet, to date few examples exist of how this concept can be applied in design practice. From a conceptual level, unobtrusiveness generated a constrained focus for us to carefully attend to the form, presence, and behavior of the Capra Collector. It required us to carefully think through how we could craft a design artifact on aesthetic, practical, and technical levels that remained open to engagement yet easily faded out of view while hiking. This meant creating a device that was wearable in a subtle, compact form that prioritized human-nature interaction. We also designed interactions with the Collector to be highly constrained, only allowing for it to be powered on, paused, shutdown, and removed or attached to one's backpack. These design decisions aimed to implement unobtrusiveness by adjusting the Collector's design to avoid disrupting physical movement as well as mental focus while on the trail.

Despite the minimal features and form, field testing revealed that the Collector did shape our attention outdoors as experiences with it accumulated over time and we became sensitized to the perspectives on, journeys through, and elements of nature it was capable of recording. Although we could not immediately 'see' what photos were captured through the multiple angled cameras, the presence of their 'potential capture' could become notable while hiking. The offset portrait timelapses prompted curiosity around what might be recorded and, equally, what might be obscured within the seams of each unit of three photos. As the Collector became a more familiar companion on hikes, we felt, at times, inclined to detach it and capture timelapses from environmental vantage points beyond our own body. When later viewed through the Explorer, we found these disembodied perspectives could provide markers of unique shifts in pacing toward slower moments of dwelling in, attuning to, and noticing elements of nature that complemented our first person hyperlapse movement on the trail. Although the Collector shaped portions of our hikes, it did so in a way that foregrounded the hiker's agency to choose to explore and consider human and non-human elements noticed in nature and how they might become integrated within hiking data, without generating disruptive frictions.

Conceptually, insights from our RtD process highlight how committing to unobtrusiveness when creating technologies for human-nature experiences remains highly important, while also acknowledging that the presence of any technology will have a mediating effect. In our case, the in-situ presence of the Collector offers potential to catalyze experiences of noticing and nature connectedness that might unfold over a longer-term timespan. While examples are limited, much design research to date has focused on building new systems to aid people in noticing by directly augmenting their interactions while being in nature, for example through wearable devices that sense and present data related to mushroom foraging [62] or a sensing application that translates soil qualities (e.g., moisture, temperature) into real-time musical compositions [63, 115]. These forms of direct intervention offer a productive pathway to notice and connect to the many entangled non-human entities one can encounter in nature. Our research complements and extends this work through proposing an alternative interaction model that emphasizes a slower, more piecemeal and accumulative approach that pairs unobtrusiveness and interactivity. This strategy can be applied in future research through designing new systems that specifically account for occasional, yet ongoing cycles of unobtrusive data collection and direct exploration, tempered with periods of non-use over a longer temporal trajectory.

On a practical level, future research that aims to work with unobtrusiveness as a design resource to facilitate noticing and human-nature interactions will likely require longer-term design processes. Only through time and iterations of pause, reflection, and interpretation were we able to judge where undesirable technological disruptions might emerge and how human-nature relations may be shaped as instances of data collection (and exploration) began to accumulate and direct our attention on the trail. As concerns of sustainability, ecological thinking, and human-nature interaction continue to grow in HCI (c.f., [10, 43, 63, 109]), our work generatively contributes to calls for new methods, techniques, and interaction patterns for supporting diverse forms of noticing and human-nature relations.

5.2 The Transfer: Exploring Pre-Interaction to Foreshadow Interconnections and Change over Time

Designing for anticipation is an ongoing area of interest in the HCI community, where it is commonly characterized as occurring in two temporal phases: first, before an experience as tension builds, and second, when tension is released as new content is revealed. Research has shown that designing for anticipation can be important for slow technology artifacts because it can lead to sustained interactions that can enable them to become embedded in people's lives over longer periods of time (e.g., [41, 76, 99]). Recent research has proposed *pre-interaction* as a productive design quality for priming experiences of interpretation with personal data. While promising, only a handful of design artifacts exist that mobilize this approach [78, 98, 105] and none explore it in the context of hiking data. Our work extends this research area by demonstrating a new form of pre-interaction that can foreshadow interconnections among new and older digital records of hikes as they become an integrated whole within the archive, while remaining open-ended in terms of when the hiker decides to engage in direct interaction.

The Transfer of data following a hike offers a unique touchpoint that conceptually and practically brings the Collector and the Explorer together as a complete artifact. This touchpoint notably (and intentionally) departs from the unobtrusive character of the Collector as slowly changing hiking data is projected into the room, marking the home as a context where rituals of exploration, noticing, and revisitation of hiking data can unfold, while the trail remains the space for data capture and human-nature interaction. Rather than treating data transfer as a mundane or invisible process, we saw it as an opportunity to situate the hiker as an active participant in the practice. The concept of pre-interaction opened a frame for us to consider how the transfer periods could be mobilized as an occasional, yet re-emergent 'time' following a hike to make present the growing and changing nature of the Explorer archive. Our aim was to manifest subtle references to temporal, altitudinal, and chromatic interconnections that were forming among new hiking

data as they slowly became entangled with all other previous hikes data.

Yet, we found tensions emerged as many of our early attempts of putting these ideas into practice emphasized direct comparisons of similarities across hikes (e.g., hiking time, time of day, similar altitudes, etc.). Upon reflection, we found these forms too heavily pre-determined the types of connections the hiker might arrive at. They left considerably less space for situated experiences of interpretation and reflection over time — a key quality of slow technology that we aimed to satisfy. Inspired by research articulating the value of leveraging highly minimal user interface aesthetics to support open-ended experiences [74], we moved to a more subtle, minimal design aesthetic. This shift appeared better capable of supporting a range of experiences — from curious attentiveness; to pause and reflection; to simply being dwelled with in the background of domestic life. Situated understandings of the archive as a whole may shift as the hiker transfers more hikes to the Explorer, providing intermittent yet ongoing opportunities to consider its growth and aging. This design case illustrates how the temporal frame of pre-interaction may evoke a quality of gradual co-evolution among a hiker and their hiking archive in the longer-term across a lifelong practice. It also reveals how data transfer is a largely overlooked but potentially important touchpoint that can open a space for priming alternative data encounters, offering a unique generative space in between data capture and interaction.

In this way, our work responds to calls for more research investigating how materials, forms, and computation can be brought to together to express the accumulation and movement of time through personal data archives [58, 78, 85, 104]. It also responds to research calling for strategies making data encounters 'placeful', situated, and local through new forms that can be lived with as everyday resources [24, 54, 69, 82, 108] and, equally, be put away [44, 55, 73, 76].

5.3 The Explorer: Open-Ended Interactions that Scale Through Interconnections Over Time

Our proposal of the Capra Explorer contributes to a corpus of HCI research that aim to support alternative, interpretive, situated encounters with personal data [24, 29, 60, 91]. We offer a design exemplar that, from the beginning of the design process, considered how a hiker might explore their data as it grew, evolved and scaled over a lifetime. In pursuing this goal, our work offers a case exemplifying how *implicit slowness* [75] can be mobilized through extending a high degree of control to the hiker while still retaining core qualities resonant with slow technology — requiring time to interpret, understand, and become attuned to.

The exacting precision afforded by the time, altitude, and color metadata encoded into each photo enabled us to develop a novel interaction design for the Explorer that allows the hiker to move between single hikes and the entire archive, while not predetermining where they may 'step' next on their journey. These three forms of metadata offer distinct, yet related modalities that can be catalyzed into differing phenomena to notice and attend to through retrospective exploration and, indeed, on the trail as well. Switching modes between specific hikes and the global archive offers a novel interaction that supports growth and evolution. While the Explorer only has a small set of hikes, each hike may be recognizable and the interconnections easy to anticipate. Yet, as more hikes are accumulated, interconnections will grow rapidly. This makes archive mode a unique resource to journey in and out of various hikes across the archive as known or unknown connections across hikes are revealed. Our approach also extends control over three forms of metadata filters that offer unique pathways through hikes previously undertaken. Over time, the hiker may become aware while hiking that particular colors, levels of altitude, or times of the day in their current hike with the Collector are forming deep interconnections to other places, ecologies, memories, associations, and moments bound up in the archive. Indeed, these interconnections evolve as new hikes are interwoven into the archive and as a hiker's own relation to hiking in nature shifts over their life.

Our research validates proposals from prior work [16, 18, 38, 42, 74, 85] that demonstrate how chronological and non-chronological metadata can operate as resources for supporting digital wayfaring in ways that lead to interpretation, reflection, and contemplation with personal data. We extend this emerging research space by illustrating how integrating other expressive forms of metadata, such as altitude and color, beyond a sole focus on temporality can generate divergent ways of seeing and revisiting different dimensions of human-nature interactions and, more generally, life experiences that scale over time. Recent research has proposed other forms of data collected in the wild, such as moisture [62], temperature [19], soil movement [63], sunlight [24], atmospheric carbon [12] and forest soundscapes [3], as additional alternative modalities that could aid in noticing and nurturing human-nature interactions and relatedness. Our research contributes an interaction design strategy that could be mobilized in future research to integrate and explore such individual and interconnected qualities across these types of data, and the different types of alternative perspectives they could generate on a hiker's relation to nature and hiking over time. In this way, our work sheds new light on how data (and metadata) captured through specific long-term practices, like hiking, is an underexplored and potentially valuable approach to guide future work in creating systems that co-evolve alongside people. In this, we see an opportunity to investigate how new systems can be designed that fit in, resonate with, and enhance people's lifelong practices.

5.4 New tools and approaches for interrogating forms of metadata as design materials

Our design-led research shows a clear need for new types of interactive tools that could better support interaction designers working with multiple forms of metadata as design materials. Through our process of creating the Collector we arrived at *time*, *altitude*, and *color* as three forms of metadata that we speculated would offer rich resources for supporting open-ended explorations of one's hikes. As we gathered data through using the Collector, we organized and queried it within a database, yet there were no readily available design tools to creatively explore this data as a design material. This barrier initially complicated our ability to understand the nuances of each form of metadata, the interrelationships among them, and the different perspectives they might offer in a single hike or across all hikes in the archive.

To work through these challenges, we initially developed custom Processing sketches to visualize the photos with the data. This allowed us to find *interconnections across* the hiking data archive through the time, altitude, and color filters. This move proved crucial for developing the foundational structure for the Explorer's interaction design and helped us grasp how time, altitude, and color could operate as resources for open-ended exploration. We next began iterating higher fidelity designs in Sketch; however, we encountered a problem. We needed a way to quickly draw the real data inside Sketch to explore how to style it. We solved this problem by developing custom Sketch plugins. We could run a color or altitude query in SQLite, copy the results, then paste that into our Sketch plugin. The plugin instantly built the color bar or altitude graph with up to 1280 data points from the database. This allowed us to create a range of visual resources and design exemplars quickly and iteratively, using our actual data, to get to the finalized UI. Our journey of exploring the possibilities of time, color, and altitude data was a messy mixture of Processing sketches, SQL queries, Python scripts, and Sketch plugins. These experiments helped us get a grasp on how we might conceptually and practically mobilize the metadata to offer open-ended ways of considering, noticing, and exploring the sheer size and scale of lapse photography hiking datasets.

These collective frictions present barriers for design researchers to generate new perspectives with personal data. They also intersect with growing calls in HCI for a multiplicity of approaches to "breaking data free" such that it can be given new forms that are self-determined, interpretive, and dynamic [25, 91, 106, 107]. Extending recent research on what data 'is' and 'could be' as a design material [18, 59, 60, 80, 100], there is an opportunity to create new tools that support designers in organizing and giving form to different temporal, spatial, and chromatic patterns in large and growing personal archives (e.g., archives of digital records of hiking). Similar to how our experiments with Processing and Sketch plug-ins were critical in developing the Explorer interaction design, such tools could actively support the development of rich creative resources that can be scaffolded in the next phase of the design process. We imagine tools and resources like this will help to respond to calls for the HCI community to create design artifacts that lead to alternative expressions of data in everyday life [29, 32, 80, 89], resist objective views of data [69, 91], and embrace "the deeply local, interpretive, and dynamic nature of data" [24:2].

6 CONCLUSION AND FUTURE WORK

Through grounding our design-led research in the proposal of Capra, our work aims to contribute to growing calls in the HCI community to create design artifacts and exemplars capable of a) opening broader possibilities for forming alternative interpretations of personal data; b) creating technologies that privilege noticing and nurturing human-nature relations over utility and quantified analysis; and, c) extending concepts of slowness and temporality through design. Our detailed unpacking of the Capra Collector, Transfer, and Explorer as an interrelated design research case offers insights into how hiking data might be captured, dwelled with, and explored in ways that foreground human agency and co-evolve alongside hiking as a lifelong practice.

Our research also uncovered numerous frictions that emerged when temporal matters bound to our conceptual aims clashed with technical precarities and potential instabilities. These findings make clear that investigating the design space of occasional yet ongoing interaction over longer time periods may require new commitments to longer-term design research processes. They also signal clear challenges and potential limits that researchers will face. A notable limitation of our designer-researcher approach is that our research is constrained to first-hand experiences of making Capra. In our future work, we aim to conduct field studies to capture, reflect on, and unpack people's experiences of hiking and living with Capra. Importantly, our aim is not to be conclusive. Rather, we aimed to unpack and critically reflect on Capra in a generative way to inspire future design research. We hope our critical-reflexive designer-researcher description of Capra, and discussion of resulting opportunities and challenges it raises, can be appreciated as an effort to communicate design-oriented forms of knowledge production in the HCI community.

ACKNOWLEDGMENTS

This research took place on the unceded ancestral territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh Úxwumixw (Squamish), səlilwətaʔɬ (Tsleil-Waututh), qi̓cəy̓ (Katzie), kʷikʷəƛ̓əm (Kwikwetlem), Stó:lō Coast Salish, K'ómoks, Tla'amin, Qayqayt, Kwantlen, Semiahmoo and Tsawwassen Nations. These locations are rooted within Indigenous lands and nations. We informed ourselves through the native-land web application (native-land.ca) to acknowledge and critically consider the land that we walked on as a part of this project. Acknowledging traditional territories, nations, and lands can be an initial step toward challenging the underlying colonization bound up in standard Western maps, and lead to further exploration and understanding of the history and complex effects of colonialism. This research is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) (RGPIN-2018-06273), the Social Sciences and Humanities Research Council of Canada (SSHRC) (435-2020-0752), and the Canada Foundation for Innovation (CFI).

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