Exploring the Reflective Potentialities of Personal Data with Different Temporal Modalities: A Field Study of Olo Radio

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ABSTRACT
We describe a long-term field study of *Olo Radio*, a music player that lets people re-experience digital music they have listened to previously. Olo Radio offers different 'timeframe modes' for organizing one's personal listening history data, and for exploring possible connections among songs and across time. We deployed 5 Olo Radios in 5 households for 8 months to understand participants' experiences over time. Our goals are to: (i) investigate the reflective potentialities of personal data for memory-oriented music listening and (ii) empirically explore conceptual propositions related to slow technology. Findings revealed Olo Radio became highly integrated in participants lives and triggered reflection on past life experiences. They also showed that Olo Radio was perceived to subtly change over time, and open up different ways of experiencing time. Findings are interpreted to present opportunities for future HCI research and practice.

Author Keywords
Music; Personal History; Temporality; Slow Technology.

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

INTRODUCTION
Today, many people's practices of listening to music are mediated by data-driven digital technologies and services. Currently, users of the service Spotify listen to over seventy million hours of music from their collections daily; and, over one trillion songs are streamed annually worldwide through digital music services [36]. As a byproduct of the uptake of digital music applications, vast archives of personal listening history data are generated that log exactly what music a person listened to and when.

These shifts raise new issues for the HCI community. The scale of contemporary listening history data archives creates new opportunities for people to reflect on their tastes, emotions, and memories bound up in music from their past. However, there is limited knowledge on what strategies or concepts could help frame design inquiries to better support and sustain reflective experiences with personal history data. There are also growing calls in the HCI community to develop alternative approaches to designing interactions with personal data that better support experiences of contemplation, interpretation, and slowness (e.g., [7,12,20,57,58]). Yet, examples illustrating how such engagements with personal history data can be mediated through the creation and study of new design artifacts remains relatively sparse in the HCI community.


Figure 1. David's Olo Radio kept in his living room.

Our research precisely focuses this intersection. We want to investigate how making people's listening history data more materially present and interactive with different temporal modalities might open potentialities for memory-oriented music listening. We also want inquire into personal life history as an aspect of temporality raised by *slow technology* [19,20] and explore how this framing might offer a rich way to support experiences with personal data that change over time. In this, our aim is to use Olo Radio as a device to empirically explore conceptual propositions related to the slow technology design philosophy.

To pursue these research goals, we conducted an 8 month field study of *Olo Radio*—a music player that uses a person's listening history archive (via Last.FM [62]) to embody the lifetime of digital music they have listened to. Inspired by prior research on designing for slowness [19,20,34], key qualities of Olo Radio's design include it: *takes time to understand*; *manifests change through time*; and *leverages different forms of time to prompt reflection by manifesting their presence in everyday life*.

Olo Radio explores different temporal modalities by using the temporal metadata associated with each instance in

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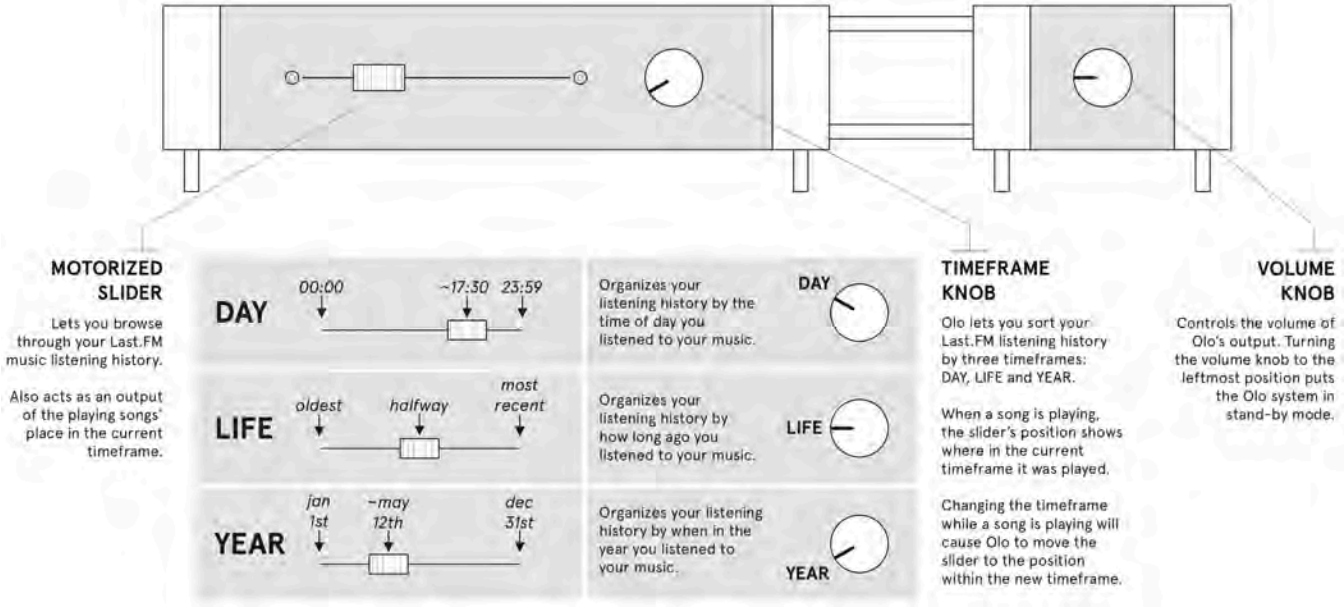

Figure 2. Explanation of the features, timeframe modes, and interaction design of Olo Radio.

which a song was previously played, to enable the user to interact with music from their past through both chronological (*Life*) and non-chronological (*Day, Year*) timeframe modes (see Figure 2). Different modes can be selected and toggled by the knob next to the motorized linear slider. The specific position of the slider is encoded to a specific 'point in time' in the user's past that is relative to the timeframe mode. When Olo Radio is turned on, it begins playing the song queried from the slider's current position. If left untouched Olo Radio will continuously play music, slowly moving forward in the timeframe mode. If the slider is moved, the current song will fade out and the song at the new location 'in time' it arrives at will fade in. If the timeframe mode is changed while a song is playing, it will continue to play as the actuated slider moves to the position in time where that instance is located in the new mode. In effect, the playing song remains unchanged, but the sequence of all listening instances surrounding it have been reorganized based on the newly selected mode.

Olo Radio offers direct control to the user to change the timeframe modes and the position 'in time' that the slider represents whenever desired. This creates an opportunity for the user to explore a range of possible connections across different songs listened to at different points in time in their past. Yet, Olo Radio's design is intentionally minimal. It takes time to understand, recognize, and interpret memories bound up in one's personal history.

We created and deployed 5 Olo Radios in 5 households for 8 months, using them to open a dialogue with participants about the reflective potentialities of memory-oriented music listening technology; and, to probe on their experiences of living with this device through the conceptual lens of slow technology. Findings revealed Olo Radio became highly integrated in participants lives and led to a range of reflections on its role in mediating recollections of memories bound up in their music listening history. Findings also showed that Olo Radio triggered diverse experiences of anticipation, opened up different ways of experiencing time, and was perceived to subtly change over time. This paper makes two contributions. First, it provides insights on how a design artifact can support memory-oriented music listening by making one's listening history data accessible through different temporal modalities. Second, it offers a case that helps expand strategies for designing slow technologies that can be accepted into people's lives and change with them through time.

BACKGROUND AND RELATED WORK

Related work falls into three areas: digital music listening; personal data and history; and slowness and temporality.

Digital Music Listening and Design Research

The digitization of music and emergence of streaming services have extended people's capacity to amass vast personal archives of music. Research in DIS and HCI has investigated new advances that this changing landscape opens for music consumption (e.g., [4,21,30,48,60,61]). Yet, these shifts have also produced unintended consequences. Personal listening histories lack the material presence that might enable people to casually engage with them in daily life [47]. Music streaming services tend to stress the discovery of new music [27], which, while valuable, can inhibit people's use of digital music to 'look back' on the past. Prompted by these issues, researchers have argued there is a need to understand how new technologies are shaping people's relations to music [54].

A growing strand of design research has begun to explore these intersecting issues through the creation of new design artifacts. The *Tangible Jukebox* [11] and *Music Cube* [1] demonstrate novel spatial and multimodal approaches to interacting with digital music playlists. *Pick up and Play* offers a "radically simplified interface to music" consumption by attributing specific playlists to tangible

cubes to create new playlists [37:10]. *MuRedder* [28] explores the concept of ephemerality by using paper tickets as song tokens that are shredded as the song plays. *Olly* [45] also explores a highly restricted interaction design through a music player that randomly selects music from its user's past, only offering the choice of whether or not to play the music when the selection occurs. The systems reviewed here explore either novel interaction techniques *or* very constrained ways of interacting with digital music. *Vintage Radio Interface* [24] offers a rare example of how one-dimensional analog controls can be used in compelling ways to offer *some control* for users to navigate their digital music archives. We aim to extend this research through studying a music player that uses analog controls to offer a high degree of tangible interactivity for users to explore their listening history which is counterbalanced by a highly minimal interface. We contribute insights on how these design qualities can work together to support rich reflective and interpretative music listening experiences over time.

Personal Data, History, and Recollecting the Past

The HCI community has an ongoing interest in understanding how personal data mediates experiences of self-reflection and reminiscence. Prior work has focused on the design of technologies that extend data, such as images or audio recordings, to cherished objects (e.g., [9,39,49]). Researchers have also begun to explore opportunities for enabling people to re-experience data from their past with photos, emails, and social media (e.g., [18,25,55,57]). Leong et al. [29,31] found that re-experiencing one's digital music can trigger experiences of serendipity. Little work has explored the design of new systems that make use of people's vast listening history data as a resource for reflection. Design researchers have also argued there is a need to design interactions with personal data that expand beyond "an exclusive interest in performance, efficiency, and rational [self] analysis" [7:48]. Yet, examples of new design artifacts that demonstrate how such rich engagements with personal data can be supported are sparse [6,7]. Our work explores the reflective potentialities that listening history data might offer when embodied through Olo Radio. We discuss opportunities for memory-oriented music listening and the roles that alternative representations of personal data could play in opening a space for exploring one's life history from different perspectives over time.

Designing for Slowness and Temporality

Considering the scale and depth of different points in time that are captured in people's listening history archives, we see an opportunity to explore how this data could be re-experienced through a temporal lens. In their original works on *slow technology* Hallnäs, Redström, and Mazé argue that design practice must expand to create "technology that surrounds us and is a part of our activities over long periods of time" [20:161] and inquire into "what it means to design a relationship with a computational thing that will last and develop over time." [34:11]. They call for design initiatives that amplify *time presence* in everyday life and reveal an expression of present time that is slower [19,20]. Since these early works, there has been a growing interest in exploring slowness as a frame for the design of interactive systems. Grosse-Hering et al. [17] designed a series of juicers to support meaningful interactions by slowing down key parts of the juice making process. Galani and Clarke [10] designed an augmented reality museum installation that leveraged slowness in support of imaginative experiences. The Long Living Chair [51] displays a record of the amount of times people have sat in it to prompt reflection on this object's lifetime and one's relation to it.

A handful of works have explored how slowness could support meaningful experiences with digital data. Examples including the Reflexive Printer [59], Photobox [43], Olly [44], and Postulator [22] provide early evidence that slowness can be a resource for supporting rich experiences, such as anticipation and reflection. While these systems are promising, they typically enforce a 'slow' pace by restricting nearly all control people have over the system itself. Little is known on ways of effectively mobilizing slowness through design in ways that offer people some control over the system, while not compromising the richness of this approach. Additionally, Pschetz and Bastian [52] argue that, while well intentioned, projects aimed at designing for slowness may result in an oversimplification of the dichotomy between fast and slow by treating 'time' as solely a matter of pacing. They highlight the need for research that explores temporal diversification through design and people's lived experiences of it. Our work aims to contribute to these strands of research on slowness and temporality. We want to explore how a new kind of music player can offer control over different temporal perspectives on one's personal listening history. In this, we explore factors shaping the extent to which it can sustain reflective and ongoing experiential qualities emblematic of slow technology's conceptual proposal and vision.

METHODOLOGY

Previously, we described and reflected on the process of designing an earlier version of Olo Radio [41]. We extend this work by conducting a long-term field study of a highly finished version of this device. Our process was influenced by the concept of *research products* [46]–design artifacts that are created to drive a research inquiry and that have a high quality of finish such that people engage with them as is (i.e., a thing), rather than what they might become (i.e., a prototype). Research products are created to operate independently for substantial time periods to support long-term field studies in people's daily environments. Thus, we needed to create a research product version of Olo Radio to understand participants' longitudinal experiences with it and how they might change over time. This approach is particularly well suited for supporting empirical studies of slow technologies because these design artifact often take time to understand and require experiences and interactions accumulate with them through time. We created a small batch of Olo Radio research products. Next, we summarize

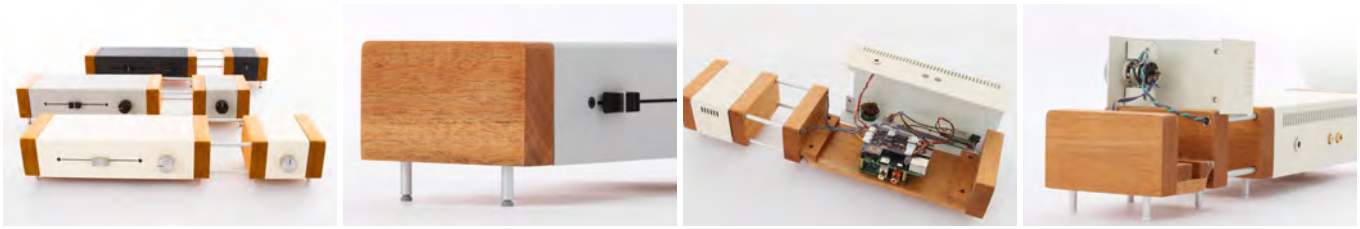

Figure 3: Left to Right. The three colors of Olo Radio; End-grain side of the slider cabinet; Rear-view of open slider cabinet featuring custom PCB, Raspberry Pi, & Hifi Berry; Rear-view of open volume control cabinet with cabling running through custom brass screws.

parts of our design process to highlight important qualities of the research product version of Olo Radio.

Design Process and Implementation

The design of Olo Radio is highly influenced by conceptual propositions that we distilled through close readings and iterative discussions of the original slow technology articles [19,20,34] among the design team. An abbreviated set of propositions that shaped our framing include the following. Slow technology is a technology that: a) *requires time to understand*; b) *considers quality of fit when in the background of human perception and when in use;* c) *changes through time*; d) *leverages different forms of time to prompt reflection by manifesting their presence in everyday life*. We are also interested in building in support for control of the system and interactions with different temporal modalities. We want to understand how these design qualities might shape participants' experiences over time. Next, we briefly elaborate on key parts of our process and their connection to our research goals.

Developing & reflecting on Olo Radio's infrastructure

Olo Radio works by linking to a user's Last.FM account. Last.FM [62] is a free web-based application that runs across a user's personal computer, smartphone, and peripherals to generate precise records of each song they have listened to in terms of the time, date, artist, song, and album (e.g., if listened through Spotify, iTunes, etc.). In existence since 2002, Last.FM offers unprecedented access to its users' listening histories. We also decided to use Last.FM data because it is a relatively open platform which makes it easier to work with listening history data (e.g., as opposed to Spotify or other listening services that do not allow end users to download or access their entire listening history data in a raw form).

We developed a Python script that generates a daily updated database of a user's entire listening history. The database of listening instances is spread across 64 'containers' mapped to discrete, evenly distributed points on the slider. In this way, Olo Radio *manifests change through time* by continually representing the embodiment of one's personal listening history each time it is encountered and by re-distributing each container's contents as new listening instances are recorded.

On the backend, three versions of the 64 containers are created, one per timeframe mode, and stored in memory to ensure there is no lag if the timeframe mode is changed. We created a Mopidy music server on a Raspberry Pi 3, and, via the Spotify API, used it to push a specific listening instance paired with a unique Spotify ID to a Spotify account dedicated to Olo Radio to play the song. Here, we are using Spotify to simply play back songs in a user's Last.FM account. Also, by using a dedicated Spotify account for each of the 5 Olo Radios helped us avoid creating a feedback loop in which older entries were reintroduced into an Olo Radio user's Last.FM account. Thus, Olo Radio sits outside of the direct infrastructure of our participants' music listening applications; it does not directly influence nor can it be controlled by other services. One limitation is that each participant's Last.FM database is cross-referenced with the Spotify library and songs that are not available are excluded from the final dataset. Spotify offered the most diverse music library available. For the participants in our study, we were able to create a dataset of 85-95% of their overall archive that were in Spotify's library. This is an issue tied to shifting international licensing agreements, among other things. This tension prompted us to consider Strauss and Fuad-Luke's Slow Design principle of *reveal* [56] where the origins of product's materials and their journey to becoming integrated in the final form are foregrounded as significant part of the design. In our field study, we saw this as an opportunity to probe participants' perspectives on the origins of their listening history data and the embodiment of most (but not all) of it in the form of Olo Radio.

Integrating temporal modalities & a minimal interface

A central part of Olo Radio's interaction design is a motorized linear slider whose form alludes to a timeline. This slider is used to navigate song instances in one's listening history archive. Three different 'timeframe' modes are used to organize a participant's listening history, which are mapped to the linear slider. ***Day*** organizes all instances based on the specific time of day they were played, from 00:00 to 23:59, to open a space for exploring memories potentially evoked by the cumulative musical soundscapes that might shift over one day. ***Life*** organizes all instances in a more traditional timeline from oldest (when one started their Last.FM account) to most recent (today's date). ***Year*** organizes all instances based on the time of the year each song was listened to, from January to December, to enable a calendrical or seasonal way of re-experiencing one's music. If the timeframe mode is changed, the currently playing song will continue to play as the slider moves to the precise position where that metadata instance is located in the new

Figure 4: Left to Right. Darius' black Olo Radio in his townhouse living room; Tim's grey Olo Radio in his parent's home living room; Jess' black Olo Radio in his apartment living room; Leslie's white Olo Radio after unwrapping just prior to installing it in his apartment.

mode (see Figure 2). Taken together, the *Day, Life*, and *Year* timeframe modes enable Olo Radio to manifest and move across chronological and non-chronological organizations of one's listening history. These interactive temporal modalities aim to embody *different forms of time* and make them more present in everyday life.

Importantly, we intentionally designed Olo Radio's interface to be highly minimal. It offers no explicit information about the specific listening instance of a song that is being played or the overall archive itself. As one's archive grows larger the granularity across the slider timeline will slowly decrease. Inspired by the proposition of creating technology that *requires time to understand* and, related work on ambiguity [14,15], the aim of these decisions is to use minimal feedback to catalyze a range of experiences that can evolve as one develops a sensibility for 'reading' and exploring Olo radio over time.

Crafting a small batch of Olo Radio research products

In our research product version of Olo Radio, we created a custom control board that integrates a capacitive touch chip, motor driver, and voltage regulator to interface with a Raspberry PI 3 and enable the slider to provide rapid input and output as it is interacted with (see figure 3). We integrated a HiFi Berry DAC+ Pro shield to provide 192kHz/24bit high quality audio that terminates to RCA outputs. This enables Olo Radio to be connected to a range of amplifiers, speakers, or receivers. Olo Radio's form is comprised of steel, aluminum, and wood. We painted 2 white, 2 smoke black, and 2 grey steel enclosures (5 were deployed). The steel enclosures screw into a wooden chassis that we crafted from Honduran Mahogany. The aluminum tubes that give Olo Radio its distinct features are hollow, enabling us to run cabling between the two cabinets. Collectively, these choices evoke an aesthetic that references vintage stereo receivers, while departing enough to suggest that Olo Radio is a new kind of music player.

Participants, Data Collection, and Analysis

We recruited 5 participants from Vancouver, Canada to participate in our study. Similar to the aim of the original technology probes paper [26], we aim to first focus on a smaller selection of participants to gain a rich, descriptive understanding of the space as a whole to inform future research and practice. We recruited participants through flyers and online advertisements. We use pseudonyms to describe our participants in this paper. All participants had sizeable Last.FM archives; and, due to their interest in Last.FM, they likely already had some interest in their past music tastes. It is important to note that 4 participants are male (1 non-binary). We selected these participants during our recruitment process because, taken together, their Last.FM accounts showed considerable diversity in terms of size and age. Our participants are:

- **David** (late-20s, poet & restaurant chef) lived with 3 other roommates in a shared house. His Last.FM account was created in 2006 and contained 181,646 listening history instances at the start of our study.
- **Darius** (early-30s, electrician) lived with his long-term girlfriend in a townhouse. His Last.FM account was created in 2010 and contained 36,072 entries.
- **Tim** (early-20s, brewery technician) lived with his parents in their house. His Last.FM account was created in 2013 and contained 41,687 entries.
- **Jess** (mid-30s, technical writer) lived alone in an apartment. Their Last.FM account was created in 2010 and contained 63,608 entries.
- **Leslie** (late-20s, graphic designer & musician) lived in an apartment with his girlfriend. His Last.FM account was created in 2010 and contained 129,672 entries.

We aimed to collect descriptive accounts from participants about their experiences with Olo Radio. Each participant had an Olo Radio that was connected to their Last.FM account. During the first home visit, we wanted to develop an understanding of participants' daily lives and practices. They gave us a home tour and decided the location of their Olo Radio. All situated it in or near their living room and connected it to their home speaker system. We offered a demo of Olo Radio, and provided a pamphlet explaining how it works (the content of this pamphlet is similar to Figure 2). We did not require participants to interact with it and noted we want them to develop their own interpretations based on their desire to use (or not use) it. All were aware they could drop out of the study at any time.

After the initial visit, we conducted bi-weekly interviews over 8 months to explore participants' unfolding experiences with Olo Radio (these sessions lasted 30-60 minutes). Considering the goals of our study, we were interested in probing on the degree to which Olo Radio may evoke reflective, temporal, or slow experiences in these interview sessions. At the conclusion of the study, we conducted in depth interviews (these sessions lasted 60-90 minutes). We often referred to fieldnotes and recordings that captured participants' earlier experiences to explore

possible changes in their attitudes toward Olo Radio. All interview sessions were audio recorded. Relevant segments of recordings were transcribed. Researchers took fieldnotes during each interview. Field notes were reviewed immediately following each interview, and tentative insights were noted in reflective field memos [16]. Analysis of the data was an ongoing process. After each visit, we conducted a preliminary analysis, searching for emergent, stabilizing, and shifting patterns across our data to draw out underlying themes [38]. We coded raw documents with these themes. We also created affinity diagrams to model connections and differences among participants.

FINDINGS

Next, we present examples taken from field interviews that help best illustrate themes in our findings, with a focus on how Olo Radio mediated experiences of listening, anticipation, reminiscence, and time.

From early explorations to integrated patterns of use

The *trajectory of appreciation* [13] is a model of user acceptance (or rejection) of new technologies that are introduced into people's everyday lives. While a new technology may initially be embraced due to its novelty, as this period fades and if people's expectations are unmet, it may be rejected. If accepted, people's experiences with the new technology may improve as it is adopted into their everyday lives. A key goal of slow technology is to create technologies that have the capacity to become deeply integrated into people's everyday environments over long time periods. Prior slow technologies have encountered tensions that complicate acceptance as frustration emerged for participants due to a lack of control over the devices they lived with (e.g., [23,40,43,45,59]). While our participants could decide when they wanted Olo Radio to play music, they still had little choice over which *specific songs* would be played and a lack of awareness of *precisely when* they were originally listened to. We expected these design qualities to result in tensions similar to prior studies. However, they largely did not emerge. For example, **Tim** described how Olo Radio's design took time to interpret, while being relatively free of initial tensions:

"Early on, it became clear I'm going to need to take my time in understanding this thing. It was challenging, in an interesting way. Not confrontational …Moving to places [on the slider] honed my focus. …I wouldn't describe it as a form of search exactly. It's a loose navigation through musical sequences and patterns that make up my history. This changed my mindset when listening. I'm more aware. …Like during the song transitions [from one to the next]. There's clues in there that often job my memory."

Participants also reported that the ability to control toggling between Olo Radio's timeframe modes offered a way of hinting at the origins of a listening instance, while evoking interpretive or reflective experiences:

"It took some time to get used to it. Olo creates arrangements that I'd never considered. [The] Year and Day modes can be perplexing because they stitch together different points in time in non-linear way. …Switching between [modes] to see where a song was from [in Life mode] would give me a hint and get me thinking on different times when I was listening [to it]. This gave it a kind of mysterious quality that kept it intriguing" (**Darius**).

These examples help illustrate that, despite its minimal design qualities, Olo Radio was able to become integrated into participants lives in ways that were largely tension free. They also begin to show that participants experienced Olo as a device that presented challenges that would require time to decode. Next, we explore this theme more deeply through describing different experiences of anticipation that emerged as participants lived with Olo Radio over time.

Experiences of Subtle and Active Anticipation

As our study progressed, it became a common theme that participants' perceptions of their Olo Radio were, in part, shaped by anticipatory interactions with their listening history data. These experiences were commonly described as emerging from Olo Radio's unpredictable nature; and, included both subtle and more active forms of anticipation.

Subtle Anticipation: configuring time for interpretive listening

Subtle forms of anticipation often involved two phases. First, manipulating the slider and timeframe knob to 'set' Olo Radio to a position in time and prospectively anticipating what might be revealed prior to hearing the music. Second, listening to the songs that played, contemplating connections among them, and anticipating what might play next. This theme is well represented by **David's** account of 'studying' his Olo to assume a reflective, anticipatory mindset before turning it on:

"I'll study where I've set [Olo] first, [and] closely look at the mode and where it's at [motioning to slider], before switching it on. …I'm getting into a mindset where I'm questioning what I might hear. I'll take a few minutes. *Then* turn it on and let the music flow into my headspace and jostle up emotions and memories. I don't know what will play first in the queue or what comes after. But, I can *anticipate* what the vibe might be. …[I] focus on the feeling of pinpoints in my past slowly being reconstructed through each song."

In a related account, **Leslie** describes a crescendo of anticipation emerging after not initially recognizing music playing from deeper in his past:

"[The slider] was pretty far to the left [in Life mode]. When I turned it on, I didn't recognize the song. Like, not at all. This piqued my interest. I settled in for a [listening] session. …Over time, I started to get a better bearing on it. …[It was] from back in [my] early college days. I was exposed to a lot of genres that were totally new to me. After identifying where I was [in my past], I felt a slow rumbling of excitement in guessing what [music] would come next. …it was like having an internal dialogue between my college self and myself now."

Leslie's account highlights how subtle anticipation with Olo Radio can accumulate into deeper experiences of reflection and introspection. This theme is well captured in **Jess'** meditative-like practice of using their Olo Radio:

"I took to blocking off time to use it. It was less of a casual thing for me. …I'd start with *Life* mode. I'd pick a position, turn [the

volume] up, lie on the couch, and close my eyes. …I'd get a vague idea of where I was [in time]. A pattern would eventually emerge. [Songs would] sometimes spark a flash of a specific memory, like a date I was on years ago or visions of my parents' home. …I'd start to get these tense feelings about what the next song would be. *Where would it bring me back to?* …When I was in the zone, time flew by. I could listen for an hour without really noticing."

Jess further reflected on how their practice evolved as they began using non-chronological timeframe modes:

"They required even more careful listening. I felt a similar eagerness for discovering the next song. But, the nature of my experience was different. I'm not being transported to 'one' time in the past. …If I'm hearing songs connected together by the time of the day, they're revealing something, but I have to work to put the pieces together into a story. It's a pattern, but I need time to decipher it. …to wait for the songs to come and contemplate the meaning of each one, and how they fit in the whole sequence [of songs]. …I'm anticipating how the next song will contribute to a narrative that's *across my life*. Not on a specific time *in my life*."

Jess' account of shows the role that different timeframe modes can play in priming different experiential forms of subtle anticipation to emerge. Taken together, the examples covered in this section illustrate how Olo Radio mediated experiences of subtle anticipation. After initially configuring Olo to a point in time and priming a space for reflection, participants took time to interpret the music that was surfaced and played back. This led to anticipation around how songs in the sequence might shape the emotional quality of their experience or contribute to a unique narrative of their personal history in or across time.

Active anticipation: cycles of explorative interaction

Our study also revealed a range of active anticipatory interactions with Olo Radio. These instances were also characterized by two distinct phases. First, participants experienced an insight often associated with a memory or emotion triggered by the song that was currently playing. Second, they then interacted with the device, typically moving across different timeframe modes to explore if that song appeared 'in time' (along the different temporal axes of the slider) where they anticipated it would. **David** offers an account of how his interactions with the timeframe modes led to growing anticipation that culminated in finding a valued playlist from his past:

"It was playing on *Day,* just in the background. …This Daft Punk song came on. *That* caught my ear. I sensed it could've been on a playlist I'd listen to before my [ski] competitions when I was younger. …I switched to *Life* and the slider shot back to the start [of my Last.FM]. This was years ago, so it would've been around the right time. …I anticipated *Year* would put [the slider] somewhere in the winter months. And, it did! I put it back to *Life*. …The next one in the queue was a Chemical Brothers song. And that's when I knew I was in my old playlist."

As this interview progressed, **David** reflected further on the quality of this experience and how his anticipatory interactions set the tone for the deep listening that followed:

"It was not just that I heard my old playlist that made this experience standout to me. Part of it was recognizing that Daft Punk song and then working with Olo to get viewpoints on where it was located in time. …It's an unusual way of 'using' technology. What I mean is I interacted with it, but never changed the music [that was playing]. …I was like orienting around different vectors in time-space. That provided some clues. And *that* started to build my excitement. …I felt a real release when the Chemical Brothers came on. It all came together to set the tone for transporting me back to when I was younger and made this playlist. I listened to it all the way through. It felt engrained in my history, even though I hadn't listened to it in ages."

Other instances emerged where participants anticipated specific temporal connections would be attributed to a song, but were met with unexpected patterns after interacting with the timeframe modes. Consider **Tim's** reflection on encountering a listening instance's unanticipated origin:

"A *Black Keys* song from the *Brothers* album started playing [when in *Year*]. That's been in my rotation over the past year since their new album came out. I was feeling the song, so I flicked it up to *Life*. I expected it'd shoot to in one of the recent times I'd played [the album]. But, it [the slider] landed near the beginning of my account. I would've been 15 or 16 [years old]. It then occurred to me that my Dad might've picked that song. He got me into the *Black Keys*. The next song wasn't the *Black Keys*, it was [from] the *White Stripes*. My Dad definitely picked that one. This changed the whole way I experienced the music. It took on a strong emotional overtone. …my Dad's fingerprints were on that– that part of my [Last.FM]. It's literally a soundtrack of my life."

Collectively, the findings in this section highlight ways that Olo Radio's form of interaction and temporal modalities shaped participants' experiences with their Last.FM data by priming both subtle and more active qualities of anticipation. They show that Olo Radio catalyzed experiences that were surprising, interpretive, introspective, and which could be "slowly rumbling" or where "time flew by." Next, we dig deeper on temporal dimensions participants experienced with Olo Radio, and perceptions of authenticity bound up in their digital listening histories.

Origins, temporal threads, and change over time

A core aspect of Olo Radio's design is that it continually updates and, in effect, embodies the near totality of one's listening history. As noted earlier, due to the limits of Spotify's library, each participant's device represented between 85-95% of their listening history. In moving from Last.FM to Olo Radio some instances are unable to be queried, making it a near, but not fully, complete history. In our final interviews we probed participants' perspectives on this issue, and, more generally, how Olo Radio shaped perceptions of their respective Last.FM archives over time.

Ambivalence over origins and authenticity

Participants commonly communicated a sense of ambivalence over the emergence of a 'near-complete' listening history archive as it moved from Last.FM's servers to their Olo Radio. **Leslie's** statements exemplify contrasting sentiments expressed by our participants:

"It makes me think if [Olo] is supposed to contain my history, then how authentic is it if there are parts missing? How does this affect which memories have a chance of being stirred up? …Who knows what kind of combination of laws and politics are at fault here. …I'm sure my history will continue, but access to *listening to it* feels somewhat fragile."

As our discussion progressed, **Leslie** reflected on the relation that he formed to Olo Radio in light of these issues:

"It's made my Last.FM data into something that is actually valuable. I've never had a strong connection to the [Last.FM] website. Olo has made my data come alive. …There's a sense of scale now to my [listening] history that I can grasp. Olo feels like is the true or 'real' form of my Last.FM data. …Because I can explore and live with the memories captured in it. So, my Last.FM [archive] it's a much more meaningful part of my life, even if it isn't 'perfectly' complete."

The comparative reflections described Leslie above were common perceptions held across participants. However, **Darius** offered a salient point on longer-term implications that can result from 'blackspots' emerging in one's digital history when devices and services breakdown:

"Living with [Olo] has opened my eyes to how my life is implicitly recorded in my listening history. It's also made me realize how vulnerable my listening history can be. …When I upgraded my phone, some apps didn't install correctly, including Last.FM. I didn't realize it for months. This created a 'blackspot' in my history that would be hard to repair. What happens if other voids appear? …It's paradoxical. I want to have Olo exactly because it puts my history at my fingertips. But, if it's populated with blackspots, is it a genuine representation?"

Interconnections across time & cumulative change

Despite the potential fragility bound to Last.FM data and questions of genuineness it could introduce, participants described how the temporal traces across listening instances could evoke different qualities of authenticity and interconnectedness. For example, consider **Tim's** reflection from our final interview where he elaborated on his 'turning point' experience of listening to a sequence of songs picked by his father that he unexpectedly stumbled upon (initially described in the prior findings section):

"That was a 'turning point' in how I viewed Olo. …I wasn't exploring music that reminded me of my Dad. I was listening to the exact songs in the exact order that he selected. Last.FM created an imprint of him when he used [my] iTunes years ago. Listening [to it] in that moment was surprisingly powerful. But, as I thought about it more, it wasn't only that. …His 'imprint' was connected to the rest of my data and became interconnected throughout my whole history. …I visualized it like threads extending out from various points in time. In reality, this is why I accidently found it. …This made me view my listening history as being made up of a massive set of interconnections that are growing as new music I'm listening to is woven in. …I've come to see Olo as being anchored in the past, while, at the same time, having a future orientation because it keeps expanding and its history gets deeper."

The qualities of personal history, interconnection and evolution captured in **Tim's** description of a pivotal experience with his Olo Radio, also emerged with several other participants in our final interviews. For example, **David** used the metaphor of footsteps in a journey:

"Listening to music [in *Life*] is like a facsimile of periods in my past. Whether I can recall them or not, I'm listening to music grounded in a specific place in time. It's like walking in the same footprints I'd made in the snow. …But, the journey is keeps going. There's momentum that's pushing ahead in time. …changing to the [*Day* or *Year*] modes, puts me into other dimensions where time has different properties. One step forward can land me in a footprint closer or farther from the present. There'd be a reason for where I'd land, although the connection may need to sink in in order to understand it. …So metaphorically and practically Olo is like a journey on different pathways formed through time. New footsteps are added through [my] new [Last.FM] data. They create new forks that extend in multiple directions at once. So [Olo] doesn't remain in the past. It grows older as I do."

The passages from **David** and **Tim** above are exemplary accounts of how participants came to value, not only the temporal interconnections that Olo Radio 'wove' together, but also that these threads changed over time. **Jess** elaborated on these themes and tied them to their own recognized change in personal history over time:

"Over these past [eight] months, Olo surfaced things that I did not expect. It turned my Last.FM data into something else. It was no longer about musical taste. A big part of it became about exploring and recognizing change in my life."

As our concluding interview continued, **Jess** offered a key example that illustrates their change in perspective:

"I was listening [in *Day*] [set to] late at night, around 01:00 or 02:00am. Olo played a pattern that alternated between party music, like rap music, and ambient songs. …Very different genres. The pattern symbolizes two different parts of my life coming together. Part of it [the party music] is from my college years. The other, the ambient [music], is me working through the night to get past a deadline for my job. …This is what I mean when I say it was less about change in musical taste. It's about me transitioning to adulthood. The growth in this process was shown through Olo's sequencing of the music. …Olo works in way where it's not frozen in time, like a scrapbook or mix-tape [audio cassette]. …the fact that my history keeps growing, [it] keeps the narrative open for my next chapter. There's room for combining my legacy with the growing record of [my] present life. This makes [Olo] feel like what I'd call timeless. It holds my history but keep advancing in time. This combination is extremely hard to find in technology."

Darius used a similar analogy in describing the simultaneous historical and dynamic qualities he recognized in Olo Radio as he worked to place it into a category of objects he possesses:

"When I compare it to all of the things I have, it's hard to place it in a specific category. It's built to last and has a historical quality to it. …I don't see it like an heirloom exactly. Heirlooms preserve a specific point in time. They're relics, like a cliché pocket watch. …I think of it like [Olo's] timeline gets thicker as my Last.FM gets bigger. In that way it feels like it's moving into the future, not just a relic from a long time ago."

Taken together, these examples show that participants' experiences with Olo Radio remained valuable over time.

They illustrate how participants experienced Olo Radio's temporal modalities creating a dynamic and evolving quality of interconnection across their listening history archive. This catalyzed perceptions that Olo Radio slowly manifested a cumulative change that 'moved' with participants into the future, which, in Jess' case, evoked a 'timeless' quality. They also highlight the potential fragility of personal data and potential consequences that could come from relying on precarious third party services.

DISCUSSION AND IMPLICATIONS

It is clear that the changing landscape of digital music brings new possibilities as traces of people's music listening practices accumulate into large historical archives. Our work offers new insights into the reflective potentialities of listening history data when made materially present with different temporal modalities. Our findings show that a temporal frame can open rich possibilities for people to revisit and explore different perspectives on their history through their personal data. These findings also resonate with the original vision of slow technology [19,20] and offer insights that take a step toward extending this design practice. Next, we present considerations for the HCI and design communities that emerged from our work.

Expanding and sustaining anticipatory interactions

Investigations into the experience of anticipation with interactive systems is an ongoing area of interest in HCI and interaction design. In this context, anticipation is usually framed as two temporal phases: first, before an experience has happened as tension accumulates, and then, second, when tension is released and one interprets the content that is revealed (see [35:64]). Designing for anticipation is important for slow technology because it can lead to ongoing interactions that may strengthen long-term attachment. Recent works have explored how a slow, and often random, interaction pacing paired with little (or no) end user control over the system can build tension for anticipation [23,40,43,45,59]. However, design artifacts mobilizing this approach have shown that highly restricted control and unpredictability resulted in major tensions that affected people's adoption of slow technology, which presents a barrier for sustaining longer-term interaction.

Our study demonstrates how people can be extended a degree of control in ways that help alleviate frictions affecting adoption, while also expanding and sustaining experiences of anticipation. Participants had direct control over Olo Radio; and, its minimal design paired with different temporal modalities generated a sense of unpredictability that supporting cycles of anticipation and resolve. This quality of unpredictability was not random. The timeframe modes mobilized temporal patterns in participants' actual listening history in ways that took time to understand and evoked, what **Darius** described as, "a mysterious quality that kept it intriguing."

In addition to alleviating tensions around adoption, our findings show Olo Radio's design qualities invited different forms of anticipation. Participants *primed a space for reflection prior to listening* by setting Olo Radio to a point in time, anticipating what might emerge, and then engaging in contemplative listening after activating the device. This led to subtle, "slow rumbling" cycles of anticipation for participants as memories were "being reconstructed through each song" (**David**) or unique narratives across one's life were interpretively developed. Participants also engaged in anticipatory interactions by manipulating timeframe modes to "orient" around temporal vantage points and potentially uncover where they expected a specific listening instance may have originated. These interactions led to surprising discoveries that often segued into reflective or introspective listening sessions where participants ceded control back to Olo Radio as it continued to play music.

Collectively, these findings demonstrate an advance for how the HCI and design communities can approach designing for anticipation. They show that design artifacts can support forms of anticipation through direct manipulation of the system, as well as through experiences that lie outside of direct interaction. In this way, our work bridges recent research on designing for *pre-interaction* [45]—the moments of anticipation prior to ceding autonomy to a system—with techniques for supporting active anticipatory interactions. We see a need for future research to explore how these combined techniques can give rise to a wider range of memory-oriented experiences with different kinds of personal data capturing one's life history. There is an opportunity to develop design patterns that illustrate how people can modulate between *ceding autonomy* to the system to *make time* for pause and reflection, and *fluidly regaining control* to *anticipate and explore* different elements in one's history through and across time. There is also an opportunity to extend slow technology through new design research cases that explore how the amplification of different forms of time may sustain cycles of interaction, interpretation, and reflection. This suggests rich possibilities for creating exemplars that respond to calls to move beyond framing slow technology as a matter solely of speed and pacing, in favor of exploring more temporally diverse design strategies [5,32,42,50].

Manifesting cumulative change across time

Olo Radio's temporal expressiveness opened possibilities for participants' relations with it to grow over time. It slowly evolved through updating daily to capture the historical traces of participants' music listening activity. Experientially, for our participants, this meant Olo Radio represented the (near) totality of their listening history each time it was encountered, effectively bridging it from the present moment to the past in an ongoing way. It also subtly changed as the granularity of its slider gradually decreased as listening history data slowly stacked up across it. This, in turn, led to the perpetual re-sorting of the sequential order of all listening instances which generated a quality of unpredictability that was uniquely tied to patterns produced from participants' own listening practices. The timeframe

modes enabled interconnections to form and expand across all instances in participants' listening history. This generated possibilities to explore alternative perspectives on their personal history from various temporal vantage points.

These qualities came together as a synthetic experience for participants that led to increased attachment to—and blurring of boundaries between—their Last.FM data and Olo Radio as *it* became "real", "alive", or "timeless." Participants valued the potential for new listening instances to be, as **Tim** put it, "woven in" to the multiple time dimensions in their personal history. This led to relations forming among memories, experiences and life stages that were bound up in their life history in linear and non-linear ways. Such as, Tim's accidental pathway to finding an "imprint" of his father playing music for his teenage self, which connected to the same song he had recently listened to. Or, Jess' recognition of personal growth through a musical sequence that crosscut radically different life stages but were bound together by the same time of day. Findings also showed participants prospectively valued the integration of their future listening histories within their aging, interconnected, and indeterminately evolving history. This prompted positive speculations on the role that Olo Radio could play in their longer-term practices of music listening as it continued "moving into the future."

Collectively, these findings resonate with the original vision of slow technology, while offering new insights that can be mobilized in future research. They show that manifesting historical qualities of a personal archive through different temporal modalities can evoke a type of agency that is uniquely reflective of the user, that takes time to interpret, and that can scale and change over time. This suggests an opportunity to more deeply investigate how technologies can be designed that materially manifest personal history archives that co-evolve with people. Additionally, due to digital music being an immaterial and temporal media, Olo Radio took advantage of the time participants need to 'spend' to listen, absorb, and interpret music being played back from their past. Our minimal interface design and actuated feedback proved effective at offering a quick 'glance' at where one might roughly be in time without demanding attention or the need for interaction. Other forms of personal data likely will require different techniques. More research is needed to investigate how different assemblies of materials, forms, and interactivity can be designed to express the movement of time through personal data. Yet, this will be complex. Darius' comments on blackspots appearing in his Last.FM archive offer salient points on the fragility bound to digital representations of our history and issues that may be faced in the future.

Designing temporal interactions across different forms of personal history data

Enabling participants to move through gradations of time with the slider and across different dimensions with the timeframe modes knob, while remaining anchored in time by the temporal metadata of the listening instance that continued to play successfully supported a range of reflective experiences. Situating *Life* – the chronological timeframe mode – as a familiar way of organizing time provided an intelligible baseline that participants used to make sense of the more unfamiliar non-chronological dimensions of *Day* and *Year* as they modulated between them. We see an opportunity for future research to scaffold this novel interaction design approach with other forms of personal data to develop new ways that it can be applied and to better understand its limits. Future research could explore the design new systems that leverage temporal metadata as a material to combine different forms of personal data, such as photos, video, music, audio recordings, location histories, and textual data (e.g., journal entries). Outcomes of this work could reveal new ways that people might explore aspects of their life history across different temporal dimensions of their personal data. There exists a trajectory of HCI research investigating the combination of different kinds of personal media with different output modalities (e.g., [2,8]). Yet, little work has considered the role that chronological and non-chronological temporal modalities could play in offering manipulating one's historical data. How could reflective, experiences be supported through combining the history of one's photos, videos, and music listening to explore connections in and across different temporal modalities? What factors might shape the form and pacing of these different elements when assembled together? And, how might they change as interconnections among different forms of personal history data age, evolve, and expand?

CONCLUSION

We studied Olo Radio to inquire into personal history as an aspect of temporality raised by slow technology, and explore how this might offer a framing for supporting reflective, memory-oriented experiences with listening history data. Our findings provide new insights into how a temporal frame can give rise to unique ways of manifesting and interacting with data bound to one's personal history beyond a purely random approach. They also detail how physical form, personal data, and computation can come together in a design artifact to richly manifest a quality of cumulative change, beyond merely the passage of time. Our research helps take a step toward understanding how slow technology could be further advanced in design practice through an extended frame. Our work also targets calls in the HCI and design communities for outcomes that contributes to longer-term programs of design research [3,33,53]. Ultimately, we hope this research supports future initiatives aimed at inquiring into the complex and evolving subject of human relations with technology over time.

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