Queue Player: On the Anatomy of a Slow Technology for Co-Listening In, Over, and Across Time

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ABSTRACT

As music streaming libraries continually grow and digitally capture elements of our evolving life histories , finding meaningful ways to revisit, reflect on, and share these collections—both individually and socially—has become increasingly important. This pictorial unpacks the creation of *Queue Player*, a network of four domestic music players that enable synchronous distributed co-listening across geographical distance and for the long-term exploration of the collective listening histories among four close friends. Adopting a Research through Design (RtD) approach, we examine how Queue Player mobilizes a slow technology lens to support experiences of social presence, interaction, and reflection that unfold over time. We provide a detailed critical-reflective account of key design decisions and frictions that shaped the development of this slow technology research product. In doing so, we contribute insights on designing with tempo as an embodied temporal interaction modality and offer strategies for supporting ongoing engagement with collective digital archives.

Authors Keywords

Music; Slow Technology; Research through Design.

CSS Concepts

• Human-centered computing~Interaction Design.

ACM ISBN 979-8-4007-1868-7/26/03
https://doi.org/10.1145/3731459.3774483

INTRODUCTION & BACKGROUND

The rise of music streaming services has significantly shaped people's practices of acquiring, sharing, and listening to music. These practices support not only self-expression and individuality, but also social connection and interaction [22,26,54]. Often mediated by data-driven technologies, music streaming practices lead to the generation of vast archives of both personal and shared data that precisely log music listening histories. As an example, users of the popular music streaming service Spotify listen to over 165 billion combined hours of music worldwide annually [79]. However, as users' listening histories grow, they become progressively invisible, making it difficult for people to notice and engage with them [53]. Internet-enabled music applications like Spotify emphasize music discovery and fragment users' digital archives across cloud-based systems, both of which can hinder personal curation and retrospective exploration [36,47]. Yet, it is increasingly well documented that listening histories offer new possibilities for people to explore and share past life experiences captured in these digital histories, opening new design opportunities for meaningful social engagement with this data [4,26,32].

Social music listening offers a rich design space, as it encompasses both individual music tastes and the ways those tastes are

expressed and experienced within a social group. Current means for music sharing are primarily centered around asynchronous listening experiences (c.f., [12]), allowing users to share and listen to music at different points in time. However, these experiences often lack the richness and intimacy of synchronous and collocated listening [25]. Nascent HCI research on distributed co-listening [32,35,61,68] (i.e., simultaneous listening over distance) shows its potential to aid in music sharing and strengthening social bonds by bridging geographical distance through synchronous listening experiences. Still, a key challenge lies in developing effective strategies for navigating combined music listening histories. Music streaming platform features allowing for co-listening over distance (e.g., Spotify's Jam [80]) primarily focus on synchronized playback, require listeners to manually select songs, and necessitate users joining each session individually. Such features emphasize synchronous listening but offer little support for sustained interaction or ongoing social connection. How might alternative interaction modalities and design strategies be mobilized to support richer forms of remote social music exploration? How might we also design for expressions of social presence while co-listening that can accommodate the evolving nature of social relationships as they gradually unfold over time? To investigate these questions, we adopt a slow technology design theoretic framing precisely because it offers a generative framework for creating technology that is part of people's lives over long time periods through sustained presence and ongoing interaction [21:201].

Designing for Slowness and Temporality

Slow technology offers a critical framing to inquire into how longer-term human-technology relations might be supported—a growing area interest in HCI (e.g., [3,19,45,51,74]). Building on Hallnäs and Redström's slow technology design philosophy, Mazé, Vallgårda et al. [39,73] argue that designers should critically attend to the temporal form of digital artifacts "to investigate what it means to design a relationship with a computational thing that will last and develop over time – in effect, an object whose form is fundamentally constituted by its temporal manifestation" [39:11]. Within the HCI community, this design philosophy has informed the creation of artifacts that encourage ongoing and meaningful engagement with personal data histories and digital traces over time (e.g., [10,49,51,76]).

Researchers have also investigated how slowness and temporal expression can be embedded in tangible forms, exemplified in cases such as *The Long Living Chair* [59] and *Soft Fading* [14]. *The Long Living Chair* is a rocking chair that allows people to view their digital history of use, not through immediate feedback, but subtly and cumulatively over the course of 96 years. Similarly, Desjardins et al.'s *Soft Fading* is a device that records how sunlight gradually fades dyed fabric in the home, allowing users to reflect on subtle changes in their domestic environment over an extended period of time [14].

Both cases illustrate how slow technologies provide space for continuous and open-ended interpretation, and lend time for reflection not on isolated events, but on the sum of interactions as they accumulate. They also show the potential slowness has for allowing people to become attuned to their own data as it unfolds over time. This temporal attunement, while exemplified in contexts of individual users, offers a promising framing for interacting with shared data in social contexts.

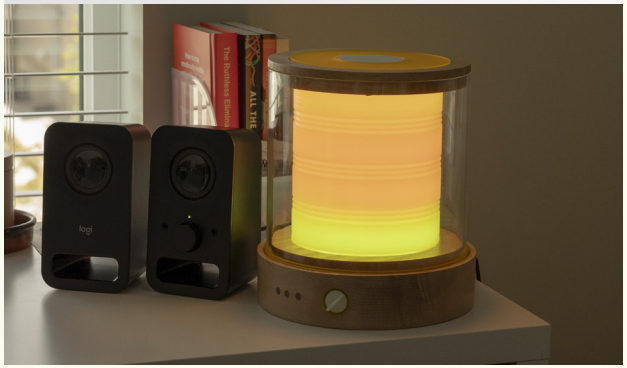
Projects including *FutureMe* [41], *Postulator* [24], and *Family-Stories* [25] offer compelling design exemplars demonstrating how a model of interaction that is slow, yet ongoing and evolving can be successfully mobilized to facilitate social interactions between loved ones, by allowing those sharing their data to engage in self-reflection, and recipients to become attuned to the shared data over time. Taken together, they show how slow technologies can provide space for reflection as people re-experience memories through shared data, whether through sharing it or receiving it, allowing new or unexpected interpretations, prompting further interactions, and the unraveling of different life-experiences.

Emerging Challenges in Materializing Temporality

Researchers have shown the value that tangible artifacts and interfaces have in social connection, and especially in fostering continuous feelings of presence and peripheral awareness between those sharing in a moment [23]. This is potentially valuable for distributed co-listening, yet researchers have noted difficulties in translating subtle computational changes into resolved physical forms [1,18].

Emerging slow technology research also highlights *temporal modalities* — the integration of various forms of time in an artifact's design — as a generative design quality for supporting reflective interactions with personal data [28,31,50,52] . Despite the potential of this framing, researchers have expressed struggles in creating technologies that sustain more occasional yet indefinite interactions [27,43,45,48]. The ongoing quality of slow technologies can also make it difficult to establish a sensibility for when the temporal pacing is 'right' [1,11,49,69].

Researchers have also emphasized the critical need to move beyond treating slowness as merely a matter of *speed* [7,45,55,58,60],



suggesting opportunities for alternative ways of conceptualizing temporality. Different temporal themes, such as biological time [33], sequential time [38], and ephemerality [15,66] have been introduced as resources for tangible interaction design. While broad, these works collectively reveal a multiplicity of ways in which temporality can be viewed in relation to designs that move beyond treating it as a matter of merely pace or direction. They also highlight the complexity of designing technologies that deviate from enacting normative conceptions of time and, in part, respond to Vallgårda et al. [71,73]'s call for more research that explicitly attends to designing the temporal form of computational objects, in addition to their physical form and interaction.

Tempo as an Embodied Form of Temporality

Tempo is a temporal modality that is not only embedded in music metadata but also reflected in the rhythms of people's daily activities and routines. Synchronous movement to a shared beat has been shown to foster trust and social cohesion in music listening contexts [64,65]. Unlike fixed or externally structured temporal modalities like

clock time, seasons, or lifespans, tempo is experiential and embodied [34:112–114], emerging from how listeners feel and move through time. As such, it holds potential to reflect or even attune to the rhythms of daily life, shared activities, or even social presence in co-listening contexts. Despite this potential, tempo remains underexplored as an interaction modality in music-sharing or slow technology systems.

Within the TEI community, researchers have investigated tempo and rhythm primarily through the lenses of dance, bodily expression, and expressing data in temporal form. For example, Perovich and Zizzi [56,77] demonstrate how dancers can engage with abstract data through choreographed movement sequences, revealing how tempo and bodily rhythm can become a medium for experiencing, interpreting, and communicating data. Similarly, Chang et al. [5] explore embodiment with Spotify data with *Be the Beat*, a system that invites users to transform their dance movements into AI generated music suggestions. Through adjusting their bodily rhythm and tempo, users can decide which songs they hear, effectively shaping their listening experience through embodied interaction.

While not directly focused on music sharing or co-listening, these works show promise for designing systems that enable people to communicate and interpret data through bodily engagement, and to gradually become attuned to their own rhythms over time. They suggest that tempo is more than a musical attribute, but also a tangible and embodied form of temporality that can shape how people engage with interactive systems and shared data. This perspective aligns with Vallgårda and Sokoler's [72] framing of temporal form (and temporal modalities like pacing and rhythm) as a material property of interactive systems, connecting tempo to broader explorations of slow technology, embodiment, and time-based design qualities.

Research Goals and Contributions

Collectively, these works highlight the need for more concrete examples of design inquires into slow technology through design practice. Our pictorial aims to contribute precisely to this area by unpacking and reflecting on the design of *Queue Player*, a network of four tangible music players that enable synchronous, distributed co-listening and long-term exploration of collective listening histories among close friends or loved ones. Queue Player enables four users to explore their shared music archive by tapping tempos on the top of their devices, adding songs at these tempos to a shared, synchronous queue. The queue is heard and seen simultaneously across all Queue Players, while subtle light indicators show when others are co-listening. Designed through a slow technology lens, Queue Player applies key theoretical concepts to explore how such a system might enable experiences that foster social presence, interactions, and both group and self-reflection that can scale over time. We focus on the particularities of design practice in envisioning and transforming the Queue Player conceptual design proposal into a highly finished slow technology research product. Research products are artifacts designed to drive a research inquiry and that have a high quality of finish such that people engage with them as is, rather than what they might become; and that operate independently in everyday settings over time [43]. Interest in developing and extending research products as a design research methodology is growing in the HCI and design communities (e.g., [2,3,6,20,37,42,44]).

Previously, we reported on findings from a field study of four Queue Player research products deployed with four friends living in Metro Vancouver, Canada [57]. In this pictorial, we build on and extend this work by offering a critical-reflective perspective on the design processes, decisions, and challenges involved in Queue Player's development—from earlier design concepts, to a conceptual design proposal, to a highly finished research product. We adopt and present a designer-researcher perspective [8,49,51], which gives prominence to the creation of real things that materially ground conceptual ideas through their actual existence—"a process of moving from the particular, general and universal to the ultimate particular–the specific design" [40:33]. This approach is influenced by practice-based works in HCI that emphasize creating design artifacts to uncover new insights that could not have been arrived at otherwise (e.g., [13,14,29,62]). Our goal is to reveal hidden challenges that can emerge when creating slow technologies and to illustrate how such challenges can be productively handled through design practice. This pictorial makes two contributions: First, it provides insights on how a design artifact works with the modality of tempo to introduce new forms of interaction for co-listeners to tangibly explore their listening history data. Second, it offers a case that helps expand strategies for designing slow technologies that can persist in people's lives over long periods of time.

RTD PROCESS TIMELINE

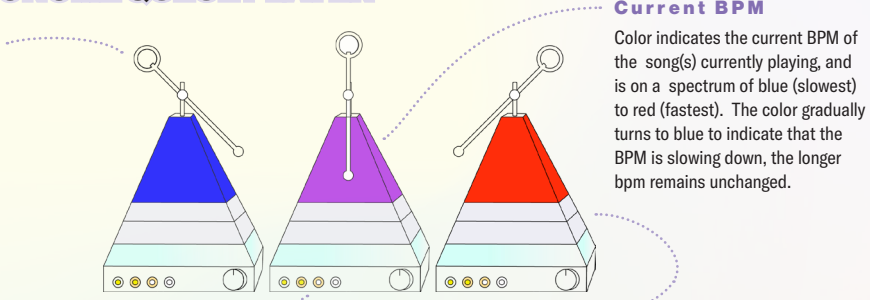
The design of Queue Player unfolded over a Research through Design (RtD) process spanning more than two and a half years, and was conducted as part of a broader project involving the long-term field deployment of four networked players distributed across four friends' homes. This timeline highlights key moments and decisions that shaped the development of the final research product.

Junkanoo, a bi-annual cultural and music festival in The Bahamas, informed Queue Player's form and algorithmic design. As a Bahamian, the first author (Pinder) drew from the festival's vivid colors, layered soundscapes, and strong sense of social cohesion to shape the visual, material, and interaction qualities of the device. The rhythmic swell of goat-skin drums—growing louder as groups drew near—inspired both the drum-like tapping interaction and the queuing of tempos to build anticipation between users.

EARLY ATTEMPTS AND CONCEPTS

As a part of Queue Player's RtD process, several design concepts were proposed to develop, explore, and critically reflect on the design space. Through an iterative process that involved several rounds of critique and discussion among our designer-researcher team, the resolved form of Queue Player was established. Here, we detail several design concepts that were not chosen, but whose design qualities and embodied aspects of Slow Technology theory were influential in informing Queue Player's final design.

METRONOME QUEUE PLAYER



Current BPM

Color indicates the current BPM of the song(s) currently playing, and is on a spectrum of blue (slowest) to red (fastest). The color gradually turns to blue to indicate that the BPM is slowing down, the longer bpm remains unchanged.

Social Presence

The inner light indicates who is co-listening, while the outer light indicates whose music library the current song is playing from.

Queue

The queue indicates that there are upcoming BPM changes. It is populated after a user has toggled the BPM, and a maximum of 3 changes can be present in the queue at one time.

Metronomes are commonly used to indicate tempo in music, producing audible clicks at a user-set pace. Théberge describes them as devices "through which one might internalize a more accurate 'feel' for musical tempo" [67], framing them as tools for embodied attunement. Drawing on this idea, an early iteration of Queue Player repurposed the metronome as an input mechanism for selecting songs by tempo. Users could pull a toggle to the left for slower songs or towards the right for faster ones, mimicking the physical motion of setting analog metronomes.

One of the strengths of this concept was its familiarity; the interaction aligned with users' prior knowledge of using metronomes to control tempo. It also hinted at a slower, more deliberate and reflective form of engagement by encouraging users to select music by tuning into a pace, which echos slow technology's aim to support thoughtful interaction over time. However, usability challenges emerged. Without visible markers or feedback, it was difficult to map tempo through toggle position alone. While incorporating markers or tactile tension were considered, they risked making the interaction feel overly rigid or quantified.

This led to a shift towards a more open-ended and intuitive form of engagement.

Later design iterations explored the use of pulsing light as a form of tempo feedback, a feature retained in Queue Player's final design.

This aimed to encourage users to sensibility to tempo over time without needing to explicitly understand tempo values.

HEARTBEAT QUEUE PLAYER

Rhythm and tempo naturally course through the human body, with heartbeat often going unnoticed until purposely checked. For this early iteration of Queue Player, the design concept centered around users momentarily monitoring their pulse via a heart rate monitor and using the reading as an input for song selection. Their pulse would also be mirrored visually through a pulsing light.

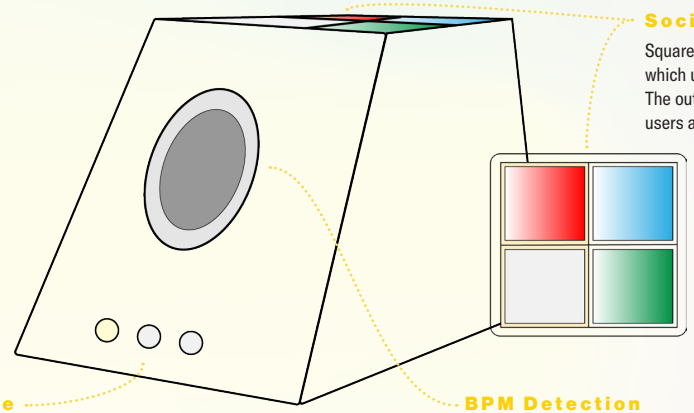
One advantage of this design was that it leveraged slow technology's emphasis on reflection. By using the body's own internal rhythms as input, this design would encourage moments of mindfulness and pause, allowing users to reflect on what they were doing and feeling before interacting with their Queue Player. However, this design was limited by the narrow range of heart rate BPM (beats per minute) values. For adults, resting heart rates can range from 60-100 BPM, with healthy adults' heart rates ranging from 55-85 BPM [78,81]. This restricted range would have possibly reduced the diversity of songs users could explore, potentially leading to repetitive or predictable listening experiences over time.

Despite this constraint, this design provided opportunities for ludic interactions as users may have attempted to modulate their heart rate through different activities. Additionally, the unpredictability of the BPM values could have introduced elements of anticipation and serendipity into the song selection process. Nonetheless, users would have had no explicit control over the tempos selected for songs, potentially limiting the personalization of their listening experience and sustained engagement with Queue Player.

These reflections prompted a shift toward an alternative design direction that still foregrounded embodiment and tempo but allowed for a broader and more intentional mapping of BPM values during song selection.

The ludic qualities of the design were preserved, enabling users to draw tempos from activities they were performing or from rhythms in their environment.

This approach promised a broader range of tempo inputs than heart rate monitoring could provide, while maintaining opportunities for playful and embodied engagement with music selection.



Social Presence

Squares will light up to indicate which users share the current BPM. The outer edge will indicate which users are listening simultaneously.

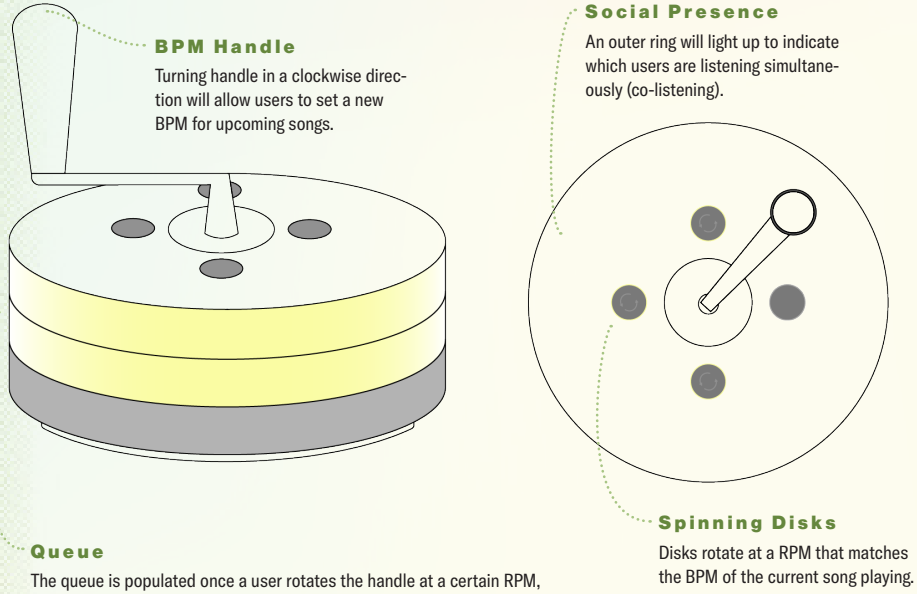
Queue

The Queue indicates that there are upcoming BPM changes. It is populated after someone reads in their current hearbeat. Once someone has a BPM change in the queue, they cannot make another change until their current change has been processed, and as long as the queue is not full. A maximum of 3 changes can be in the queue at one time.

BPM Detection

BPM is detected once a user places their index finger on the pulse reader. The pulse reader will detect the user's heartbeat using an LED, and the result will be used as a new BPM and placed into the queue. The ring surrounding the pulse reader will also display the user's heartbeat after it is detected, through a colored pulsating light.

REVOLUTIONS QUEUE PLAYER



Revolutions per minute (RPM) is prevalently seen in physical music-listening media such as CDs and vinyl records. In this iteration of Queue Player, RPM was explored as an alternative input for exploring beats per minute. By rotating a handle mounted on the top of their Queue Player, users could intuitively select a tempo that corresponded to the speed of their rotation.

This embodied interaction for song selection offered a promising method for intuitively selecting tempos, while also aligning with the slow technology concept of reflective engagement through simple and interpretive interactions.

However, with the rotational handle for tempo navigation, we anticipated that the lateral force needed to turn it could potentially cause the device to wobble or tip over, making the interaction feel awkward and physically cumbersome. The design would have also required a complex system of rotary encoders for the oscillating discs and handle to rotate as intended. Although this design iteration was ultimately not pursued, the exploration contributed key insights that influenced later design decisions.

The circular form factor proved useful for visualizing a shifting archive of music (i.e., a queue) in ways that were dynamic, richly minimal, and open to interpretation.

The flexibility of this form would allow users to view the current queue of songs from any angle, opening up more potential areas for the placement of Queue Players people's homes. The interaction of turning the handle also began to surface a more embodied understanding of tempo, which laid the groundwork for the finalized interaction of tapping. While RPM offered a metaphorical and historical link to past musical media, its mapping to BPM was too abstract and unintuitive. This led to the more direct embodied interaction of tap tempo.

TAP TEMPO QUEUE PLAYER

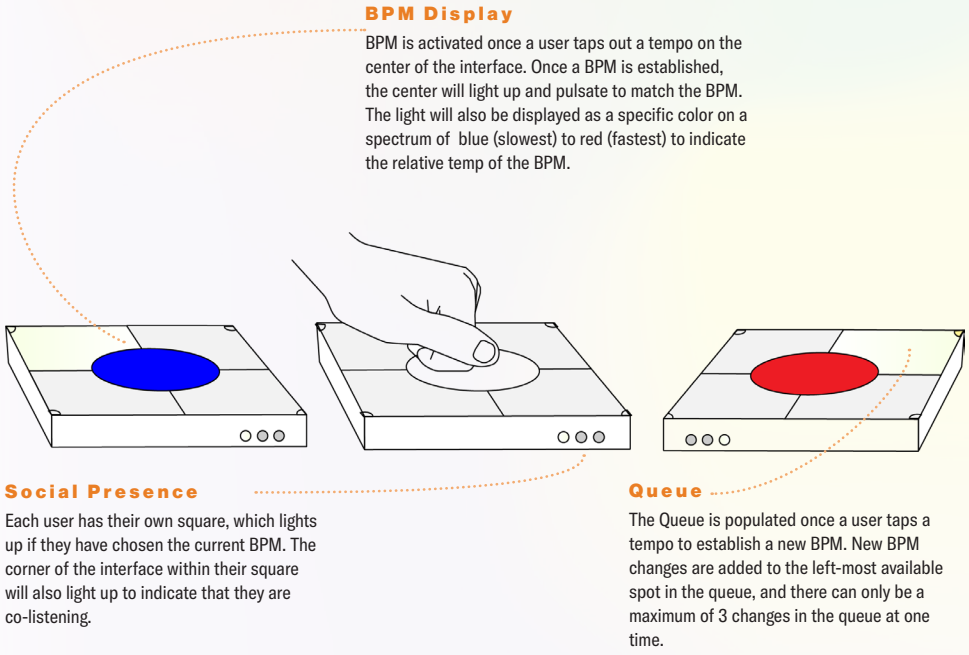
The Tap Tempo Queue Player offered a straightforward and effective interaction for users so that they could intentionally and directly control the tempos of songs played from the shared archive. This design for Queue Player would encourage users to tap on the center of their Queue Player to establish a tempo for songs to be played. Once tapped, the tapping interface would light up with a color on a spectrum ranging from dark blue to deep red to indicate slowest to fastest BPM, respectively.

Among all design iterations, the tap tempo interaction proved to be the most engaging, intuitive, yet still novel interaction. Tapping to the beat of songs is an action that many people already perform while listening to music, making it an easily replicable and familiar interaction. These qualities contributed to the decision to adopt tap tempo as the core input interaction for Queue Player.

However, the flat form factor of this design concept complicated the ability to present an embodied representation of a queue of songs to users. Users would have had to walk up to their Queue Player to see the current state of the queue or notice tempo changes. This idea also clashed with of the principles of slow technology, which emphasize the subtle and seamless integration of a device into users' daily lives.

This led to prioritizing a circular design for Queue Player that could not only subtly fit into people's homes and make it easy for users to view and engage with the queue from any angle, but also support a more ambient and embodied presence within the home.

Through iterative refinement and prototyping, this design direction evolved into the final, highly resolved form of Queue Player.



THE ANATOMY OF A SLOW TECHNOLOGY: QUEUE PLAYER

Odom et al. [48] extend the original aspirational vision of slow technology [21] , by proposing key qualities that can be worked with in the design and making of slow technologies. Here, we annotate conceptual design qualities mobilized in Queue Player's final finished form and implementation.

Implicit Slowness (A)

End-user control intentionally enables direct control of pacing

Tap tempo allows users to 'speed up' the rate at which they navigate to different parts of a collective archive.

Temporal Interconnectedness (A D)

Integrating two or more temporal modalities

Tempos contributed to the shared queue intersect with users' differing routines, shaping how co-listeners encounter and influence each other's experiences over time.

Temporal Density (A B)

Frequency of data entries, interactions, or events over time

Each user can add only one tempo to the queue at a time. By limiting this interaction, the frequency of contributions is controlled, ensuring a balanced distribution of interactions among users and equal an opportunity to influence the queue during co-listening.

Explicit Slowness (B)

Restricting end-user control so that pacing cannot be controlled

Once a user adds a new tempo to the queue, they are restricted from adding another one until that song has been played and leaves the queue. Songs cannot be skipped, and users have no control over how long a tempo remains in the queue, prompting reflection on songs as they play.

Temporal Granularity (A B)

The amount of time an end-user moves through when interacting with an artifact

To offset the vast number of songs in the archive, tap tempo allows users to tangibly control when they move to different tempos and specific parts of the archive.

Temporal Drift (A B C D)

An artifact's temporal pacing that makes it drift in and out of alignment with cyclical rhythms of people's daily routines

As users turn on their Queue Players, tap tempos at different moments, and engage with them on their own time, each device drifts in and out of temporal alignment with daily life. The shared queue can be experienced differently depending on each user's presence and routine.

Pre-Interaction (B C)

Space and time prior to the moment of interacting with an artifact

Indicator lights communicate which users are co-listening, priming other users to potentially interact with them and/or their Queue Players.

Queue lights communicate 'ownership' of a specific song but offer no additional information apart from new tempos that have been queued, prompting anticipation, curiosity, reflection, and consideration.

Ongoingness (B C)

Perpetual movement of time through an artifact

Indicator lights show those who are currently co-listening and turn on and off in real time (even when a user's own device is off) to maintain a subtle sense of ongoing presence. Song playback continues even when no new tempos are added, with the system selecting songs at progressively lower tempos within the archive, continuing indefinitely until a new one is introduced.

Temporal Modality (A)

Different forms of time which can be linear or non-linear

By organizing the archive by tempo and using tap tempo for song navigation, Queue Player allows users to explore their shared listening history non-linearly, rather than in the order songs were originally listened to.

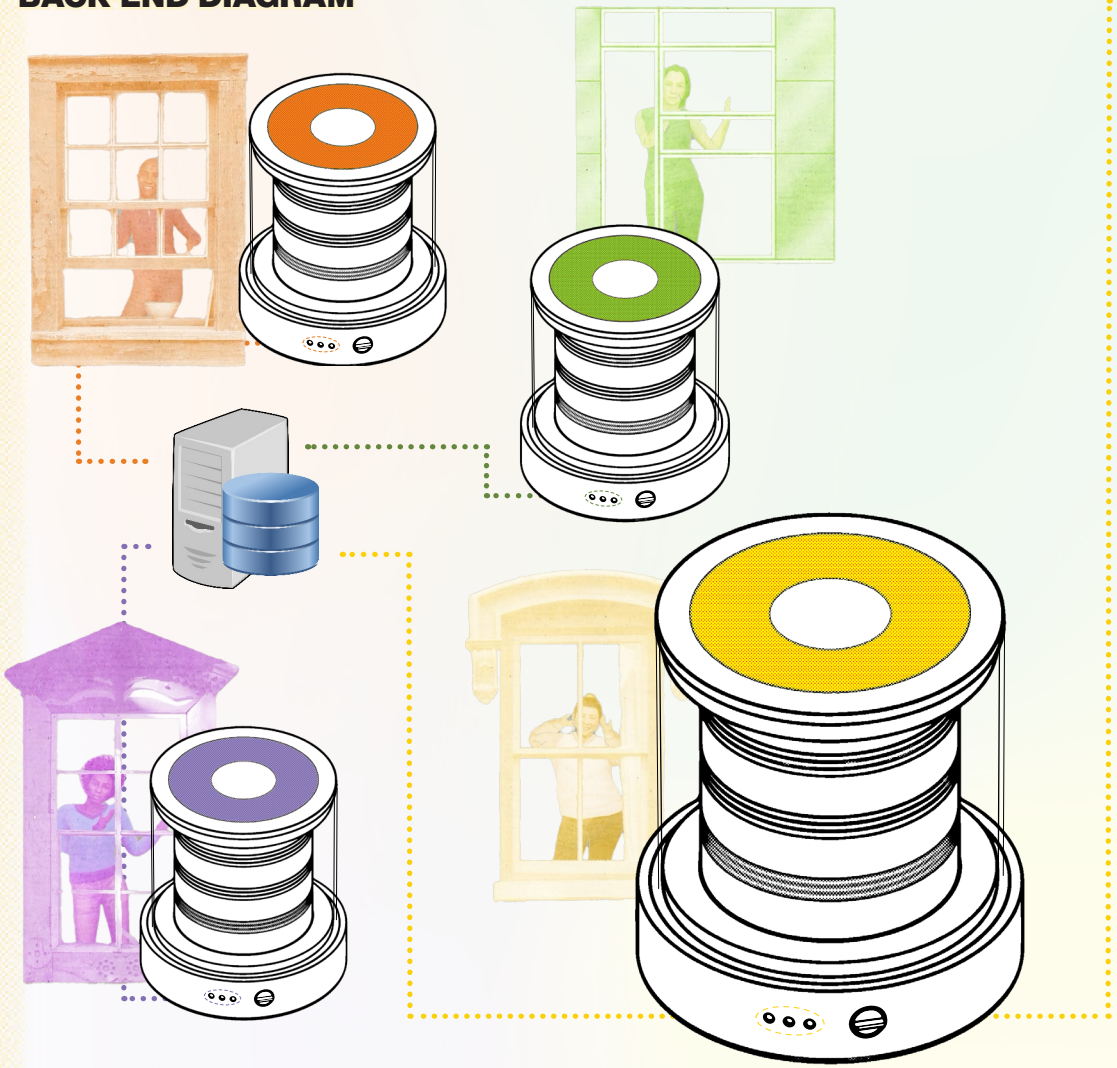
A **Tapping Interface:** Users tap a steady tempo to add it to the queue. Once the tempo reaches the top, the interface changes to the color of the user who tapped and pulses at the new tempo.

B **Queue:** Four sections light up to show upcoming songs, with the top section indicating the current song. Colors represent users (orange, yellow, green, violet), and gradients indicate users' shared songs. Dimmed sections signal a tempo change.

C **Indicator Lights:** Lights show who is currently co-listening, corresponding to users' assigned colors.

D **Power & Volume Knob:** Turning to the right turns the power on and increases volume; Turning fully left turns the power off. Once on, song playback and the queue sync with other active Queue Players.

BACK-END DIAGRAM



Pre-Processing

1. Spotify streaming histories from four users were assigned unique user IDs.
2. Data was filtered to exclude non-songs, remove duplicates, and omit tracks unavailable in our Spotify market (Spotify Canada).
3. Relevant fields (user IDs, track names, and Spotify track IDs) were extracted for each song, along with metadata that included a song's valence and level of dancelibity.
4. Songs were sorted into tempo 'containers' in ascending beats per minute (BPM) order.

Post-Processing

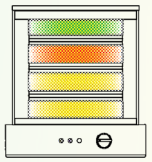
5. A JavaScript remote server handles Spotify API requests and broadcasts user states (active/inactive), track IDs, current tempo, current timestamp, and current queue colors to all Queue Players.
6. Server broadcasts are sent at the start of each track to ensure synchronization across both active and inactive Queue Players.
7. Once a tempo 'container' is exhausted, songs transition to the next slower tempo; exhausting the slowest tempo container will trigger a loop back to the fastest tempo.

For a more dynamic explanation of how Queue Player works please see: https://www.homewarelab.com/projects/queue-player

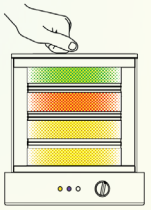
INTERACTION FLOW

1. 

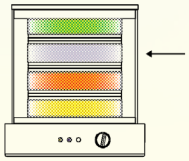
Turn the knob to the right to power on and increase volume.

2. 

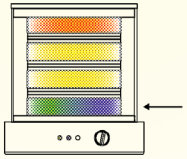
When powered on, the queue fills with songs that match the current tempo. Each section's color represents a user and a song they've listened to. The top section shows the song currently playing.

3. 

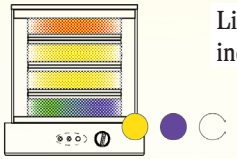
Tap the tapping interface to set a new tempo for upcoming songs.

4. 

The queue clears, keeping the top song. A new song, matching the tapped tempo, joins the queue, glowing dimly until it reaches the top section.

5. 

Songs listened to by multiple users are represented as color gradients.

6. 

Lights at the base of the Queue Player indicate which users are currently listening.

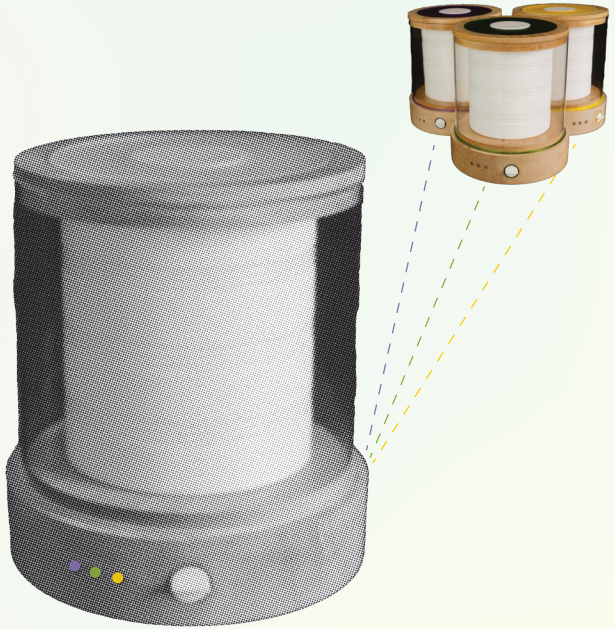
OVERVIEW OF KEY FRICTIONS

Several frictions emerged during the RtD process that were directly tied to the core conceptual vision of Queue Player as a research product, namely enabling synchronous co-listening over distance between four close friends while retaining the reflective, long-term, and evolving nature of a slow technology. Through mobilizing key slow technology design qualities outlined by Odom et al. [48], we addressed these frictions through numerous iterations across our design process which, ultimately, enabled us to create Queue Player in a resolved, finished form that could operate in everyday life over long time periods. Here, we give an overview of three key fictions that were encountered and how the design's theoretic framing of slow technology was used as a lens to navigate them.

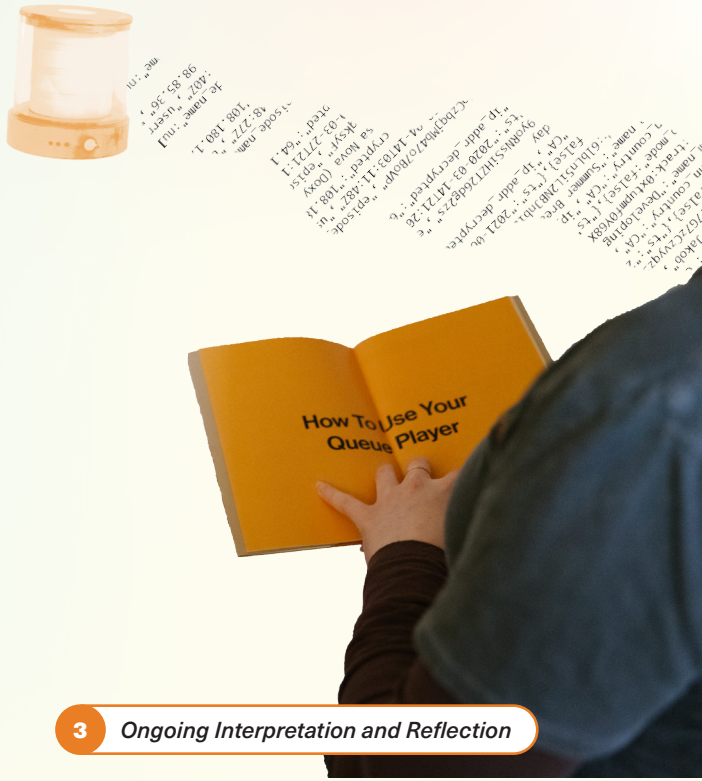
1 *Unobtrusiveness and Engagement*

Given its intended use in a domestic setting, unobtrusiveness played a significant role in shaping Queue Player's design, both in form and function. The design needed to seamlessly fit into people's homes, while encouraging social engagement over distance. Strong and Gaver [63] explain the value of unobtrusiveness in tangible devices, especially in those that enable connection over distance, as togetherness can be conveyed effectively through subtle gestures and interactions rather than explicitly shown. Weiser and Brown [75] further note that unobtrusiveness in interfaces and interactions often "engages both the center and periphery of our attention". However, the integration of hardware and software during Queue Player's development created tension between aesthetic minimalism and interaction legibility. Through several iterations informed by several slow technology qualities, namely explicit slowness, temporal interconnectedness, and pre-interaction, this balance was achieved to create subtle cues that invited interactions without being overly demanding.

2 *Subtle and Sustained Presence*



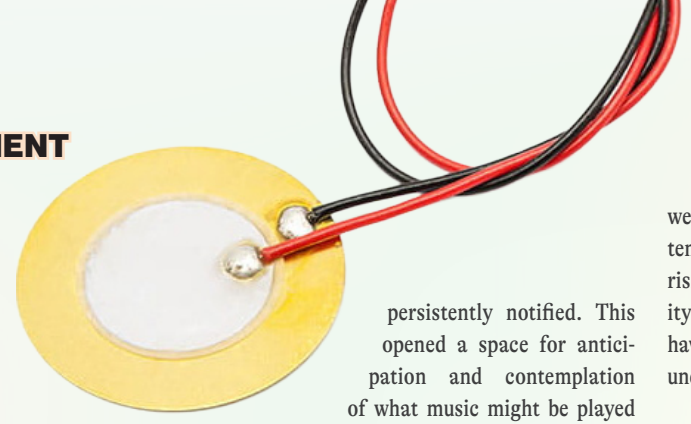
Another challenge in Queue Player's development was not only connecting multiple people synchronously across space and time, but integrating an invitation to interact with the device through social presence. The design needed to signal presence and social participation in subtle but persistent ways, especially given that users might engage with their device at different times or across varying routines. Building on Erickson et al.'s concept of social translucence [16,17], integrating aspects of visibility, awareness, and accountability into Queue Player's design by implementing a *social proxy*, described as a "minimalist visualization of people and their activities", was difficult to achieve in practice and required several design iterations. The key to overcoming this friction centered on the interplay between unobtrusiveness and awareness, which was refined through working with slow technology design qualities including temporal interconnectedness, ongoingness, temporal drift, pre-interaction, and explicit slowness.



3 *Ongoing Interpretation and Reflection*

The final friction in designing Queue Player arose from the need to ensure that its interactions were understandable while still allowing for users' open-ended exploration. Though a tempo-based input interaction was selected because of its familiarity and intuitiveness, users still had to navigate a novel device intended for exploring a collective listening history archive. It was also important that users could effectively navigate an extensive archive of their music in a way that was meaningful and retained their engagement. The balance between providing space for open interpretation of music through the embodied and experiential nature of tempo while still ensuring that interactions were easy to understand was again informed by multiple slow technology qualities such as temporal modalities, implicit slowness, explicit slowness, pre-interaction, temporal density, and temporal granularity.

1 UNOBTRUSIVENESS AND ENGAGEMENT



Maintaining a Minimalistic Design

When designing Queue Player, minimalism was central to ensuring that users could interact with the device intuitively. The cylindrical form factor suggested the use of flat sensors that could be easily tapped without disrupting the device's minimalist aesthetic, while also maintaining the drum metaphor. We avoided the use of buttons, as they disrupted the cohesive form, while capacitive touch sensors, though visually unobtrusive, lacked the responsiveness required for accurate tap detection. Piezoelectric sensors ultimately provided a more effective solution, enabling accurate detection of tempo through embodied tapping while preserving the device's simple physical presence.

Minimalism also extended to the queue lights and how the system communicated activity. Rather than providing detailed song information, Queue Player employed pre-interaction to subtly indicate the presence of new, upcoming tempos without revealing specific song metadata. Pre-interaction also informed the decision to simply dim tempos newly introduced to the queue so that users could understand that a new tempo was upcoming without being persistently notified. This opened a space for anticipation and contemplation of what music might be played prior to interaction. Explicit slowness was also embedded into the design through constraints, such as removing the ability to skip songs, and, instead, requiring songs to be listened to in full once they had reached the top of the queue. Taken together, these decisions positioned Queue Player as a device that invites users to pause and listen, rather than rapidly navigate or curate their music listening experiences.

Balancing Tempo as an Input and Output

Tempo was designed to function both as an input interaction for Queue Player, as well as a subtle ambient output to invite engagement. In this way, tempo would bridge the gap between embodied control of Queue Player and peripheral awareness users would have of both the system and of each other. Tapping a tempo would enable users to express the pace of their present moment, reflecting how they were moving, feeling, or situated in their day, and letting that embodied sense of time shape what entered the queue. At the same time, Queue Player needed to communicate the active tempo currently in the queue in a way that preserved its unobtrusive quality while still inviting continued engagement.

Rather than displaying the tempo explicitly (e.g., via a screen or LED matrix), more subtle solutions such as haptic feedback and light feedback were considered. Though users could have interpreted the current tempo in an embodied way through haptic vibration, it ultimately risked introducing an ambiguous feedback loop as the same modality would have been used for input (tapping) and output. This would have potentially hindered users from developing a sensibility to better understand tempo over time.

In contrast, light offered a non-intrusive type of feedback that could communicate tempo just as effectively, provide a separation between the input and output, and better integrate tactile and visual temporal modalities. We initially explored the use of rotating light to maintain Queue Player's circular metaphor; however, we found this this to be too visually distracting. Instead, a gently pulsing light at the current tempo, made from the color of the person who tapped it, proved to be a more balanced solution and better mimicked the tapping users would perform when interacting.

Positioning the light on the top surface of the Queue Player also allowed it to be visible from anywhere in a user's living space, inviting passive engagement. Drawing on temporal interconnectedness and pre-interaction, the pulsing light would enable users to gradually attune to the tempo alongside concurrent activities, offering possibilities for alignment or divergence from the current tempo, and opportunities for a wide range of both individual and group experiences.

This friction ultimately demonstrated how a tangible interface can merge embodied input with ambient output to enable subtle yet meaningful engagement. By avoiding overly directive cues and instead allowing tempo to be gradually perceived and felt, these decisions foregrounded tempo as both an experiential and expressive material, while still maintaining the unobtrusiveness of slow technology artifacts.

2 SUBTLE AND SUSTAINED PRESENCE

Making Presence Subtle but Meaningful

Since we distributed the Queue Players across four separate households, each device needed to signal when users were actively co-listening to enable feelings of presence and connection even over distance. Drawing on the quality of pre-interaction, three small indicator lights on the front of each Queue Player were designed to subtly show when another device was turned on.

Explicit slowness also informed in the design of the queue lights: once a new tempo was added, it remained in the queue until played. Even if a user turned off their Queue Player after introducing a tempo, others could still see the entry, providing a lingering sense of the user's presence. These deferred interactions, where past input shaped present experience, enabled a form of asynchronous bodily presence.

Making Presence Ongoing

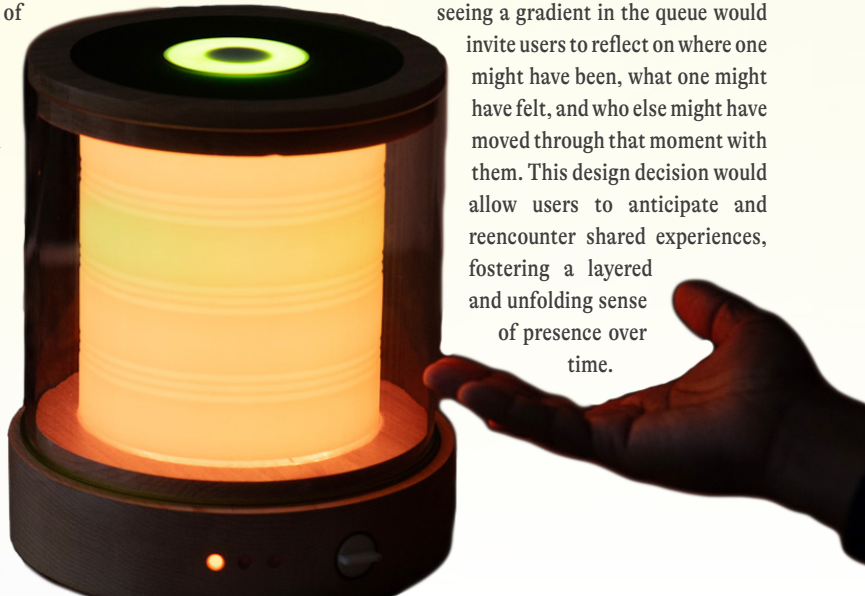
Because users followed different schedules and routines, Queue Player's design needed to support asynchronous yet continuous interaction. Drawing on the qualities of ongoingness and temporal interconnectedness was pivotal in the design process for establishing a sense of enduring presence. Indicator lights were designed to remain active even after a user turned off their device, to communicate when others were still co-listening. While this user would appear inactive to others, they could retain a passive awareness of the ongoing session and rejoin it later. To support seamless re-entry, all Queue Players continued receiving the current song's timestamp and queue information while inactive, allowing users to re-enter the listening session without disruption.

Tap tempo also served as an embodied mechanism for instilling a sense of ongoing presence through temporal interconnectedness. During testing, we found that as we moved through different moments in the day, the tempos we tapped reflected how we were currently situated—whether moving quickly during routines or more slowly during quieter periods—allowing everyday shifts in lived time to shape the listening experience. We anticipated that through users' active or passive engagement with their Queue Players, varying tempo contributions would meet others' routines at different times, allowing the queue to drift in and out of alignment with daily life. This quality of temporal drift would enable a continuous yet unobtrusive sense of presence between users.

Communicating Presence while Co-listening

One of Queue Player's primary goals is to support both individual and collective reflection on shared listening histories among friends. Since users were likely to encounter songs previously heard by multiple members of the group, it was important to acknowledge and communicate these past shared moments. Temporal interconnectedness and pre-interaction were the qualities that primarily shaped the decision to use gradient lighting to signify shared songs in the queue. These gradients blended the unique colors associated with each user who had previously listened to that song. In doing so, temporal interconnectedness brought previously unknown or unrecognized past intersections across digital listening histories into the present moment.

Simultaneously, the pre-interaction of seeing a gradient in the queue would invite users to reflect on where one might have been, what one might have felt, and who else might have moved through that moment with them. This design decision would allow users to anticipate and reencounter shared experiences, fostering a layered and unfolding sense of presence over time.



3 ONGOING INTERPRETATION AND REFLECTION

Navigating the Archive

Navigating a collective archive of listening histories presented another friction in Queue Player's development. Because tap tempo was chosen as the interaction input, the archive was organized by tempo, with songs arranged from lowest to highest BPM. Tap tempo therefore served two functions: it set the target tempo for upcoming songs and also shaped the pace of the system's gradual drift through adjacent tempos when left untouched.

This enabled tempo to act as a form of temporal granularity. By tapping faster or slower, users could 'tune' how long they remained within a given tempo range, choosing to linger or move on—much like adjusting a radio dial to dwell within a musical region rather than selecting a specific song.

During our own testing, we noticed that we often stayed in certain tempo ranges longer than expected due to the density of songs clustered around specific BPMs (e.g., much popular music is between 90-99 BPM, meaning these areas of the archive could be very populated) . While this sometimes felt welcome, it also highlighted the need for a way to step into new tempo regions more intentionally. This insight informed our decision to treat tap tempo not only as a form of selection, but also as a means of navigating the archive while maintaining an open-ended, exploratory feel.

In this way, tap tempo affords an implicit slowness that allows navigation to become felt and situated for each user, rather than directed solely by the system's pace.

Creating Variability in Listening Sessions

To prevent repetitive listening experiences and sustain curiosity over time, we incorporated Spotify's valence (a song's emotional quality) and danceability (the suitability of a song for dancing) metrics to further refine the sorting of songs and provide a sense of unpredictability. With each new tempo tapped, a different combination of valence and danceability values (i.e., high-high, high-low, low-high, or low-low) was used to determine song selection, playback order, and the emotional tone of songs chosen. To keep the listening experience dynamic, add granularity to song exploration, and encourage curiosity, a new combination of these values would also be chosen at the beginning of a listening session, ensuring variation between sessions and inviting users to explore the archive in fresh ways.

Through testing, we also found that incorporating these metrics made transitions less jarring. When songs shared similar emotional tone and rhythmic qualities, shifts within a tempo range, and even between tempos, felt smoother. This realization reinforced our decision to use valence and danceability as subtle ways of structuring the queue, producing variation without compromising the exploratory feel of the listening experience.

This variability complemented the embodied nature of the tap tempo interaction since the same action of tapping could lead to different emotional qualities for listening sessions depending on the underlying metadata. Rather than mapping tempo to a specific emotional quality or level of danceability, this ambiguity was designed to support slow technology's goal of encouraging ongoing reflection and reinterpretation. Over time, users could begin to associate particular bodily rhythms with different emotional qualities of songs, deepening their attunement to the archive and reinforcing a temporal connection between mood, activity, and music. In this way, variability became a means of a slow and embodied way of engaging with personal and collective listening histories.

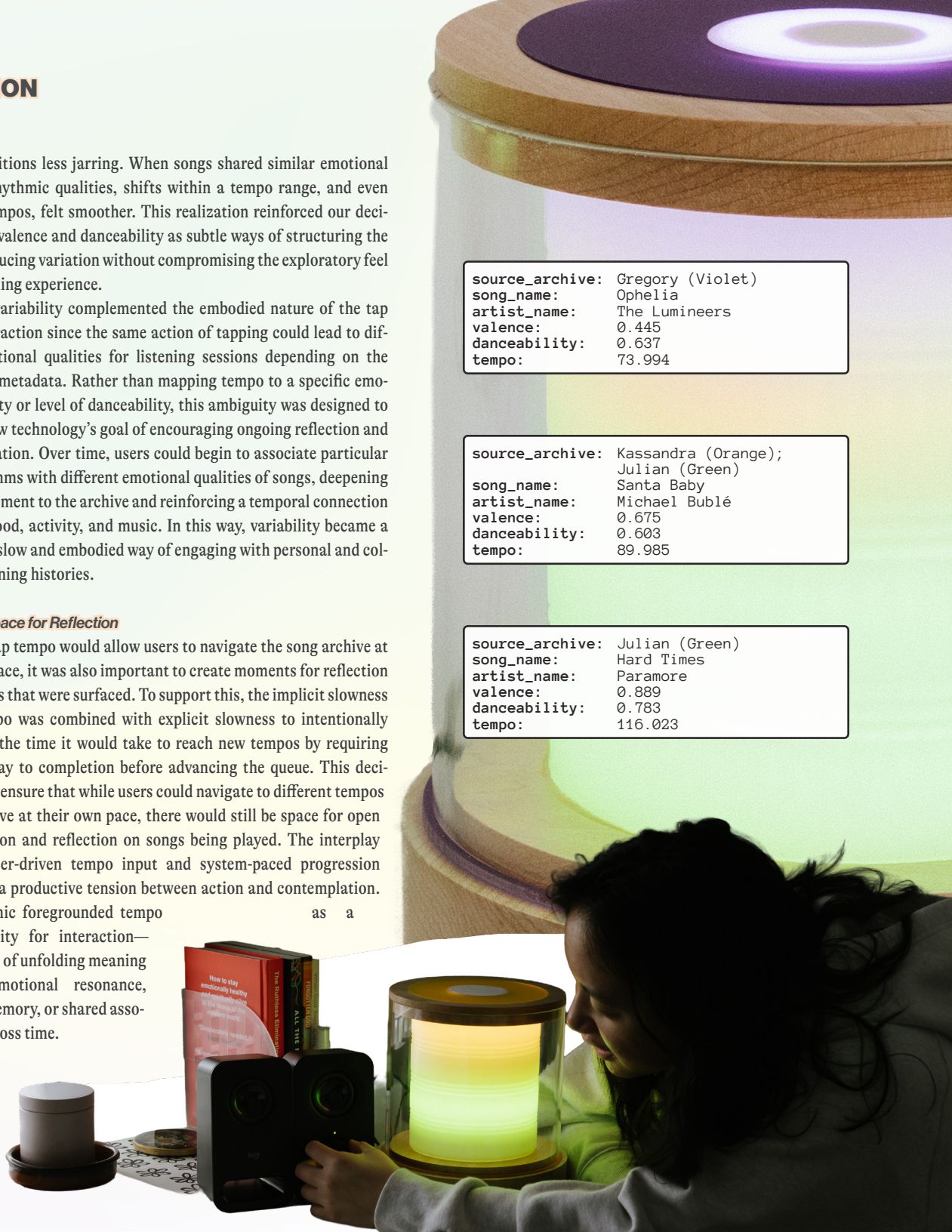
Creating Space for Reflection

Although tap tempo would allow users to navigate the song archive at their own pace, it was also important to create moments for reflection on the songs that were surfaced. To support this, the implicit slowness of tap tempo was combined with explicit slowness to intentionally slow down the time it would take to reach new tempos by requiring songs to play to completion before advancing the queue. This decision helped ensure that while users could navigate to different tempos in the archive at their own pace, there would still be space for open interpretation and reflection on songs being played. The interplay between user-driven tempo input and system-paced progression introduced a productive tension between action and contemplation. This dynamic foregrounded tempo as a rich modality for interaction—one capable of unfolding meaning through emotional resonance, personal memory, or shared associations across time.

```
source_archive:  Gregory (Violet)
song_name:       Ophelia
artist_name:     The Lumineers
valence:         0.445
danceability:    0.637
tempo:           73.994
```

```
source_archive:  Kassandra (Orange);
                 Julian (Green)
song_name:       Santa Baby
artist_name:     Michael Bublé
valence:         0.675
danceability:    0.603
tempo:           89.985
```

```
source_archive:  Julian (Green)
song_name:       Hard Times
artist_name:     Paramore
valence:         0.889
danceability:    0.783
tempo:           116.023
```



DISCUSSION

This pictorial covers over two and a half years of conceptualization, frictions, design decisions, and ultimately the creation of Queue Player as a highly resolved slow technology research product. Across this process, several frictions emerged around balancing the embodied interaction of tap tempo with design qualities core to slow technology, namely unobtrusiveness, subtle and sustained presence, and ongoing interpretation. Next, we reflect further on themes that highlight broader opportunities for future research and practice in this emerging space.

Reinforcing subtle presence and anticipation with Pre-Interaction

In Queue Player's design pre-interaction was key to subtly signaling changes in social presence and building anticipation around the evolving queue. Subtle changes in light and color allowed these cues to fade into the background of everyday life while still prompting interpretation and interaction.

Pre-interaction was also valuable in communicating the current and changing tempos. By mapping tempo to the embodied action of tapping, the design encouraged users to develop a growing sensibility to understand tempo over time and to interpret both music and their everyday surroundings more openly. Even outside of direct interaction, the presence of new tempos sitting in the queue before playback created space for reflection—inviting users to wonder what moods, moments, or activities might have inspired a particular tempo's entry in the queue.

While few artifacts deliberately mobilize pre-interaction (e.g., [50,52,69,76]) none have explored it in the context of co-listening experiences. This work extends this growing research area by showing how pre-interaction can be layered in diverse ways to overcome design frictions and produce highly finished design artifacts that exemplify the persistent, subtle, reflective and evolving design qualities fundamental to slow technology.

Intertwining Explicit and Implicit Slowness

Prior works have produced slow technologies that firmly express either explicit slowness – where end user control is highly restricted and the pacing of the artifact cannot be modulated (e.g., [31,46,59,69,70]) – or implicit slowness – where end users are extended a high degree of control and interaction, while the artifact retains inherent reflective qualities (e.g., [9,21,51,52]). While these approaches often appear oppositional, Queue Player demonstrates how the two can be productively intertwined. Its design mobilizes explicit slowness by ensuring each song plays through in full, encouraging pause and contemplation. At the same time, implicit slowness allows users to modulate tempo and explore unique temporal pathways through the archive.

This combination of implicit and explicit slowness foregrounds anticipation around what songs and memories may be surfaced from parts of the archive, tempered by moments of collective pause during co-listening in the present moment. These indeterminate experiences may potentially lead to users encountering less common tempos in the archive, as they are driven by curiosity and anticipation, or arrive at a collectively desired tempos. Over time, such interactions and explorations can accumulate, fostering intimacy and deeper understandings of shared and individual music histories.

Our unpacking of Queue Player's RtD process revealed that the space between internally sensing tempo, expressing it through interaction, and then re-experiencing it via the artifact's behavior can open possibilities for rich interaction and reflection. By combining embodied input with implicit and explicit slowness, designers can enable users to embed personal meaning into interactions while also allowing the system to respond in ways that invite slow and evolving discovery. As a design strategy, intertwining implicit and explicit slowness allows for tangible interactions that balance user agency with temporality, encouraging curiosity, contemplation, and ongoing interpretation beyond immediate feedback and direct control.

Extending Tempo as Design Resource

Prior research (e.g., [28,41,52]) has demonstrated the use of timestamp metadata as a design resource to prompt reflection on memories bound to specific time periods. This work extends those ideas by demonstrating how tempo, as a tangible and embodied input, supports non-linear, indeterminate engagement with shared music histories. Tapping tempo not only enables reflective exploration but also introduces a mechanism for surfacing emotional valences, associations, and previously unnoticed interpersonal connections within the archive.

This work also extends prior research at the intersection of tempo and emotion [30,65], suggesting opportunities for future research to further explore how tempo could intersect with other temporal dimensions—such as days, seasons, or life events—or be applied to other types of data like photos, location, or health to enrich the explorations of digital archives.

In parallel to Vallgårda's discussion of temporal form in shape changing interfaces [73], tempo expands how tangible interaction can connect bodily rhythms to broader temporalities. Queue Player embodies this through temporal drift—subtly falling in and out of sync with daily routines, allowing co-listeners to reencounter music histories outside their original context. In doing so, tempo becomes a means of fostering anticipation, reinterpretation, and emotional resonance.

In this way, tempo offers a design resource for generating unpredictability and understanding over time in a slow technology. By encouraging users to attune to how their bodily rhythms influence a tangible system—and offering the choice to either synchronize with or deviate from it—tempo enables interactions that unfold beyond linear progression, opening up spaces for exploration and reinterpretation. We see substantial potential for tempo to shape new forms of embodied, temporal, and socially meaningful interaction with personal and shared data—offering novel ways to revisit, reinterpret, and relate to digital traces as they evolve over time.

CONTRIBUTION AND FUTURE WORK

This pictorial offers a critical-reflective account of the design of Queue Player, presenting a case of RtD practice that demonstrates how shared digital listening histories can be made materially present and transformed into a dynamic resource for ongoing interaction, exploration, collaboration, and reflection. It contributes (i) new design strategies for enabling distributed co-listening experiences by leveraging tempo as a temporal and social interaction modality, and (ii) an extended framing of slow technology that combines multiple qualities of slowness and temporality into a robust, tangible research product.

For the tangible interaction design community, this work contributes to ongoing inquiries into how temporal and bodily rhythms can be meaningfully embedded in tangible artifacts. It also addresses calls to develop slow, long-term, and socially attuned technologies through a RtD approach. Future work may investigate how tempo could be applied beyond music listening—such as in personal or shared data archives—to foster socially meaningful, embodied interactions with slow technologies over time.

ACKNOWLEDGEMENTS

This research is supported by the *Natural Sciences and Engineering Research Council of Canada* (NSERC) (RGPIN-2025-04401), the *Social Sciences and Humanities Research Council of Canada* (SSHRC) (435-2020-0752), the *Canada Foundation for Innovation* (CFI), and a *MITACS Globalink Research Award*.

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