Queue Player: Investigating Distributed Co-Listening Experiences for Social Connection across Space, Time, and Tempo

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Figure 1: Left to Right: Kassandra setting up her Queue Player in her living room; Julian turning on his Queue Player in his living room.

Abstract

We describe the design and deployment of *Queue Player*, four networked domestic music players that combine music listening histories of close friends to explore new potentialities for interacting with this shared archive. We deployed the Queue Players with four close friends living in separate homes for six weeks. Our goals are to (i) explore how this system might enable co-listening experiences that foster social presence, interaction, and reflection and (ii) empirically explore conceptual propositions related to slow technology. Findings revealed that, after overcoming initial frictions, Queue Player became integrated in participants' lives and triggered a range of social interactions and reflections on past life experiences. They also showed that Queue Player provoked questions on the benefits and limits of data capturing one's life history as well as the role and pace of technology in everyday life at home. Findings are interpreted to present opportunities for future HCI research and practice.

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Keywords

Digital Music, Co-listening, Slow Technology, Research through Design

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1 INTRODUCTION

People's practices of acquiring, sharing, and listening to music play key roles in supporting self-expression, and social interaction and connection [30, 33, 63]. Today, music listening practices are often mediated by data-driven technologies and services. People listen to an average of 20 hours of music per week [72], while Spotify users, in particular, listen to over 165 billion combined hours of music worldwide annually [91]. These practices lead to the generation of vast archives of personal data that precisely log music listening histories, which raise new challenges and opportunities for the HCI community. The scale and depth of contemporary music listening history data offers new ways for people to explore, reflect on, and share their past tastes, idiosyncrasies, and memories that are captured in their archives. Yet, there is limited knowledge on what strategies and concepts could help frame design inquiries into supporting social, reflective, and expressive experiences with this data.

Spotify[1] features like *Wrapped* [93], *AI DJ* [90], and *Repeat Rewind* [94] offer some engagement with listening history data, but lack the support for users to consistently revisit and reflect on significant past moments in their lives. Sharing and reflecting on listening histories with others is equally challenging as current music sharing technologies largely cater to *asynchronous listening* experiences [10], which lack the richness and intimacy of simultaneous listening in a shared space [32]. HCI research on *synchronous* distributed *co-listening* [40, 45, 75, 80] illustrates its potential to strengthen social bonds. Still, effectively navigating combined listening histories in this context remains difficult. Current music streaming platform features that support co-listening over distance (i.e. Spotify's Jam [95]) primarily focus on synchronized playback, leaving opportunities to explore rich interaction modalities that support social exploration, expressions of social presence, and a sense of tangible persistence while co-listening. Research into slow technology highlights *temporal modalities* — the combined integration of various forms of time in an artifact's interaction design — as generative resources for supporting interactions with personal music listening histories that are reflective, interpretive, and ongoing [36, 54, 59, 62], offering a promising lens for exploring new interaction modalities that can broaden the scope of synchronous co-listening experiences over distance.

Our research investigates how the physical embodiment of people's personal listening history data, when combined with others', can facilitate rich experiences of co-listening over distance. We also examine how the combination of people's personal histories for mutual exploration might lead to opportunities for interpersonal connections and group reflections among listeners. In this, we inquire into life histories as an aspect of temporality raised by slow technology [29, 56], and explore how this framing may provide a valuable way to support longer-term social listening experiences that can scale and change over time.

To pursue these goals, we designed *Queue Player*, a music player that mobilizes tempo metadata (i.e., beats per minute) as the cornerstone of its interaction design to support open-ended experiences among a group of co-listeners (**see** Figure 1). We created four Queue Players which materialize the combined music listening histories of four close friends living apart, into an ever-changing 'queue', enabling them to traverse, experience, and live with songs from their collective pasts over distance. The Queue Players act as a network and surface users' songs from a shared music archive according to steady tempos tapped out on their respective device. Once a tempo is tapped, songs populate the 'queue' at that specific tempo and distinct colors indicate whose listening history the song came from. If left 'untouched', songs continue to play at that tempo. Any users can interject new songs at different tempos in the queue, but each song must play out in its entirety before the queue advances. Additionally, users can only add a new tempo if they don't already have one waiting in the queue.

We deployed the four Queue Players for six weeks to the individual households of four close friends to conduct a qualitative in-home field study exploring how participants might use their Queue Players to traverse their music-listening histories, and experience synchronous and equally distributed co-listening together while living apart. A primary aim for our study was to consider how participants might use Queue Player not as a replacement for their current listening practices, but as an extension of their individual and social listening habits. We also sought to understand how Queue Player might play a role in mediating social connections with loved ones over distance, and whether synchronizing the tangible experience, despite differences in their lives and routines, could foster meaningful experiences and varied emotions between them. Findings revealed that Queue Player generated diverse experiences for co-listening and revisiting one's listening history, encouraged social bonding and intimacy, evoked feelings of anticipation and curiosity through slowness, and facilitated discussions around navigating combined data histories over longer time periods.

This paper makes two contributions: First, it provides insights on how a distributed interactive system can support social connection among co-listeners by making their collective listening history data materially and tangibly accessible through the temporal modality of tempo. We see potential for tempo to be used as a means for long-term reflection in slow technology artifacts, and thus this paper's second contribution offers a case that helps expand strategies for

[1]Spotify is currently the world's most popular music streaming service [92] and provides the most features that support engagement with listening history data and co-listening functionality. While competitor music streaming services (e.g. Amazon Music, Apple Music, Deezer, YouTube Music, Tidal, etc.) do offer some functionality to engage with archives, and some limited co-listening functionality, we will draw our examples of commercial features from Spotify.

designing slow technologies that can be accepted into people's lives and change with them through time.

2 LITERATURE REVIEW

2.1 Digital Music Listening Practices: Personal and Social

Prior research has detailed various ways friends and family members use digital music applications to socially connect, by sharing music from their personal libraries with each other (e.g., [10, 28, 64]) and researchers have focused on the role music sharing plays in encouraging social cohesion [43, 74].

Music streaming platforms like Spotify have begun to explore social features that enable both synchronous and asynchronous music sharing. Features like *Blend* [96], *Collaborative Playlists* [97], and *Jam* [95] allow social groups to add, remove, and reorder songs so that they can listen together, yet with differing degrees of control over rights to music sharing. While the freedom for listeners to curate and control music-listening sessions has the potential to promote feelings of connectedness while co-listening, key limitations currently exist with both asynchronous and synchronous listening.

One significant challenge that extends to both asynchronous and synchronous music-sharing scenarios is the complexity of song selection and playlist curation. Krause et al. suggest that the ability to freely choose music often enhances music-listening experiences [42]; however, other research has shown that the option to add and remove songs from extensive collections of music, especially when several listeners' collections are involved, can diminish chances to experience anticipation and may overwhelm listeners [46, 47]. Intentionally skipping songs while listening to music with others may also evoke feelings of exclusion if one's songs are repeatedly removed or ignored, and continuously choosing music to maintain listening sessions may also become tedious to users [79] and discourage simultaneous listening over time.

HCI research exploring synchronous music sharing shows further complexities for both those who are collocated and sharing remotely. Bassoli et al.'s *tunA*, is a mobile application that allows people to see what songs other people are listening to in a shared location and listen to the songs in a synchronous co-listening experience [2]. This application enables users to voluntarily connect with others if they find their music appealing, which can support developing one-to-one bonds within a social group; however, it limits bonding among the entire co-listening group. Lenz et al.'s *Mo* [45] is a proposed collocated personal music device that allows co-listeners to play their music during social gatherings and to select and merge songs from nearby Mo's into a combined playlist, which they found to foster feelings of intimacy and serendipity. However, Mo's features for selective listening and allowing users to "pre-listen" to songs before playback restrict the amount of equal control and sense of connection among listeners. Tibau et al.'s *FamilySong* [80] facilitates co-listening across both geographical distance and generations, as it connects family members through a shared synchronous listening experience via Spotify. Findings from a field study of FamilySong revealed that user-driven song selection may prioritize crowd-pleasing over personal preference, potentially diluting the intimacy and expression of individual identity and taste in the co-listening experience. These social streaming limitations found in studies of tunA, Mo, and FamilySong point to a critical dilemma between personal music streaming and what Hagen and Lüders describe as a "valued social object" once one's music becomes a shared commodity [28]: An individual's music listening practices often captures elements of their personal lives and daily routines, making sharing them with others an intimate and vulnerable experience. Yet, sharing and entrusting parts of one's music-listening history may strengthen social bonds among loved ones, and potentially expose all involved to diverse musical tastes and interpretations of them [28, 82].

Our work aims to address the research gaps outlined above by investigating how a novel music player like Queue Player can be designed to support equal control of music while co-listening over distance.

2.2 Personal Data, and Data within a Social Context

There is ongoing interest in the HCI community in how people's personal data operate as a resource for self-reflection and recollection in the design of new technologies. This has been investigated through the creation and study of systems that resurface personal data, including photos (e.g., [6, 7, 50, 57]), location metadata [27, 84], and music listening histories (e.g., [36, 39, 59, 62]). However, these examples have only shown the value of utilizing data as a design material on a personal level. Devices that explore a combination of users' data to support group reflection and open-ended interpretation remain scarce.

Music listening histories provide insights into people's habits, behaviors, intentions with song selection, and the influence of social interactions on their music taste [28, 48, 86]. Graham et al. explain that the willingness to share personal data with others has the potential to encourage deep reflection, and prompt new and rich perceptions of one's own data due to differences in the data people collect [26]. Fleck and Harrison make a similar observation, in that sharing data with others helps individuals to better contextualize their data by itself and also make sense of its similarities and differences with others' data [18]. These findings offer promise to co-listening over distance and group exploration of one's music listening history, as individuals have unique life experiences, differing tastes in music and interpretations of songs. Co-listening may encourage people to provide more personal context to their music while others engage with it, cultivate a better understanding of oneself, and inspire more intentional music listening in personal music listening practices [86].

Our research examines the potential benefits and limitations that music listening histories have for supporting self-reflection in social music-listening contexts. We investigate and discuss how openly sharing music while co-listening may also provide opportunities to strengthen social bonds and interpersonal trust through social interactions while listening across distance with loved ones.

2.3 Slow Technology Principles in Sustained Interactions

Hallnäs and Redström describe slow technologies as those that encourage reflection and "[supply] time for doing new things" [29] through affordances. *The Long Living Chair* [66], is a rocking chair

that allows users to view how it has been used over the course of 96 years. It subtly and slowly displays each interaction, prompting reflection on sitting in the chair over time, rather than focusing on each individual use. The minimal display of how much the chair has been used promotes intentional engagement, as frequent interaction is not demanded from the user; overtime, anticipation for viewing insights into the chair's history grows. Similarly, Desjardins et al.'s *Slow Fading* is a device that collects sunlight in the home and records how it fades dyed fabric over long periods of time [13]. Like the Long Living Chair, Slow Fading emphasizes unobtrusiveness, builds anticipation for viewing how the fabric has faded through time while also fading into the background of the user's home and attention. Both cases illustrate how slow technologies provide space and lend time for reflection on the sum of one's interactions with a device, instead of isolated interactions. They point to the potential of slow technology serving as a lens for encouraging social interactions and reflections through co-listening between loved ones, as they can gradually become attuned to each other's music, potentially forming deeper understandings of shared music as it is played over time. These cases also demonstrate how slow technologies can build anticipation by dynamically presenting data in a persistent domestic location over time. Incorporating these qualities into a music player, like Queue Player, in a domestic setting, may also foster similar experiences of prolonged anticipation as music listening histories are shared between co-listeners.

Slow technology can also facilitate reflective experiences through the notion of scarcity, such as in the cases of *PhotoBox* [55] and *muRedder* [39]. With PhotoBox, photos are printed occasionally and randomly from a user's photo archive to allow them to meaningfully reflect on their photographic history and slow down the consumption of their photos. MuRedder is a shredding speaker that allows users to select song tickets to listen to songs, which are played and simultaneously shredded until the song is complete. Similar to PhotoBox, muRedder slows down the rate of music consumption so that users are able to engage with it more intentionally and over a longer period of time. In extending these works, we inquire into the potential of slow technology in co-listening contexts, and how implementing scarcity into the consumption of a combined archive of a social group's music might cultivate more intentional listening and stronger connections to music as it plays.

2.4 Tempo & Digital Music Listening

Tempo, as a specific form of input to explore one's history with any kind of personal data or media, has been underexplored in HCI research that explores navigating listening archives and is unutilized in current music-listening technologies. This research gap is especially significant in digital music listening practices, considering how readily accessible tempo metadata (i.e., beats per minute (BPM)) is. Kosonen and Eronen offer a rare example of how tempo metadata can be leveraged, in a custom music player that supports navigating a music track by measure to allow a playful and seamless exploration [41], while a handful of other studies have explored the potential for tap tempo to operate as a novel input modality for song browsing on mobile devices (e.g., [3, 11]). These examples demonstrate great promise for tempo as an input interaction for exploring one's music history due to its relatively unobtrusive and lightweight qualities, as well as its ability to be easily replicated or improvised by end users.

Tempo is inherently intertwined with people's daily activities, as they encounter varying rhythms while engaging in tasks such as cooking, cleaning, reading, exercising, or even falling asleep [73]. Further, studies show that tempo could evoke emotional perception and responses to music [38, 70]. While tempo alone does not always elicit strong emotional responses, its interplay with other musical features like dynamics and mode enhances emotional interpretation, such as how faster tempos are often associated with happiness and high-energy, and slower tempos convey feelings such as sadness or peacefulness. This interplay can create a sense of connection among listeners through shared emotional responses to music. In this way, tempo can play a considerable role in synchronous co-listening and social bonding, as it influences people's embodied interactions and emotional reactions when listening with others. Studies indicate that those who move to the same beat during simultaneous music-listening often experience synchronicity in their movements and behaviors, leading to heightened feelings of trust and cohesion with co-listeners [77, 78]. This has implications for synchronous co-listening over distance, where temporal synchrony becomes critical for co-listeners to perceive each other's presence despite geographical and time differences.

Our work explores how tempo can be mobilized as a focal modality in interaction design to encourage deeper reflections when individuals listen to and explore their music in a social context. We also examine how navigating music archives with tempo might map to the rhythms in people's everyday life experiences, and how this can support rich reflections on how music surrounds daily routines. Furthermore, we explore how embodied interactions while co-listening may support deeper social bonds, trust, and cohesion with loved ones over distance.

2.5 Designing to Indicate Subtle Social Presence

While music streaming services have made music easy to access, share, and revisit, they have also made people's interactions with music largely intangible. This poses a challenge for co-listening over distance, as many HCI studies have highlighted the importance of tangibility in facilitating peripheral awareness, intimacy, and social connectedness between those who are physically separated (e.g., [19, 37, 71]). Strong and Gaver [76] also explain the value of unobtrusiveness in tangible devices that enable social connection over distance, as togetherness is often conveyed and perceived through simple and subtle gestures that communicate emotions rather than explicit information. Weiser and Brown [83:2] echo this need for "Calm Technology", as interfaces and interactions that are unobtrusive often "[engage] both the center and periphery of our attention".

Tangible artifacts allow for feelings of continuous awareness of others' presence and the surrounding environment, without disruption to routines or any concurrent activities [31]. This persistent awareness is crucial for co-listening experiences, where physical separation impedes feelings of social connectedness. Erickson et al.'s concept of social translucence [14, 15] also outlines the concepts of visibility, awareness, and accountability within physical distributed social contexts. Extending this to co-listening, tangible,

subtle indicators of presence can prompt intentional and reflective interactions between listeners, as they become attuned to each other's presence.

Our work explores how a tangible music player can support feelings of presence, awareness, and togetherness for co-listeners who engage in synchronous music-listening experiences over distance. We also examine how subtly conveying the presence of others can prompt more intentional interactions with Queue Player, anticipation in sharing music with others, and curiosity for what others are doing and feeling in shared music-listening moments.

3 METHODOLOGY

In what follows, we present our Research through Design (RtD) [20, 88] process of creating Queue Player, which involved two distinct phases: (i) the formative phase, where we worked through conceptual and practical frictions to ultimately arrive at the Queue Player concept and (ii) the finalization phase where we produced and deployed a small batch of our networked Queue Player research products [4, 60]. We then provide details on participant recruitment, our field study, and data collection and analysis.

3.1 Design Process and Implementation: The Formative Phase

When creating Queue Player, we engaged in an iterative RtD process that took place over the course of 2.5 years. Our design research team consisted of five members with diverse backgrounds spanning human-computer interaction, interaction design, industrial design, computer science, and filmmaking. All members had an active interest in music listening and had used digital music streaming services for years. Following Zimmerman et al., we adopted an RtD process centered on "iteratively designing artifacts as a creative way of investigating what a potential future might be" [89:313]. We also adopted a designer-researcher approach, which prioritizes first-hand insights gained through the creation of real things that embody and bring conceptual ideas to life through their actual existence [5, 12, 58, 84]. Odom et al. note that designer-researchers often function as a small but multi-disciplinary team and "reflexively focus on the creative, experimental, and novel outcomes of the design process that are critically and reflectively arrived at through design practice" [61].

3.1.1 Design Concept Proposals Exploring Tempo Interactions. Our design process began with ideating several design concepts for Queue Player where we explored different ways of representing tempo in an interaction. Our first concept was a Metronome Queue Player (**see** Appendix A), and we proposed the idea of repurposing metronomes to be used as an input device for selecting tempo instead of an output device for indicating tempo. While this concept offered familiarity in form and function, we ultimately decided not to use it because of intelligibility challenges; simply toggling the metronome bar to the left and right for slower and faster tempos, respectively, would not have provided enough granularity for users to accurately map tempos. This prompted us to consider a more specific approach for expressing tempo through embodiment.

Our second concept was a Heartbeat Queue Player (**see** Appendix B) that would map a user's pulse to tempo as an input for song selection. Though this concept would have allowed users to experience and use tempo through embodiment and mindfulness, it ultimately would have given a limited range of beats per minute (BPM) values for users to explore because of the limit of heart rate ranges [98], restricting song variety and potentially leading to repetitive listening experiences. This then led us to a design where tempo could be mapped more explicitly through embodiment, but with a much broader range of BPM values for song selection.

Our third concept was a Revolving Queue Player (**see** Appendix C) which would enable users to input a BPM that corresponded to the revolutions per minute (RPM) value by turning a handle on top of the Queue Player. While this embodied form for song selection would have been promising for more directly selecting tempos, we determined that the turning interaction would have been cumbersome and mapping RPM to BPM was too abstract. However, the cylindrical form factor of this design proved useful for visualizing a shifting archive of music (i.e., a queue) in ways that were dynamic, richly minimal, and open to interpretation.

Our final concept was a Tap Tempo Queue Player (**see** Appendix D) which would allow users to tap on the center of their Queue Player to establish a tempo for songs to be played. 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. The tap tempo interaction proved to be the most engaging, intuitive, yet still novel, interaction amongst all the design iterations, prompting us to proceed with this concept.

3.1.2 Using a Slow Technology Lens: Integrating Temporal Modalities. With a design concept established, we moved towards using a slow technology lens for designing Queue Player's interactions. Queue Player's design is highly influenced by concepts distilled from close readings and iterative discussions of theoretical articles on slow technology [29, 53, 56]. Slow Technology is a design philosophy that advocates for technologies that engage users over long periods of time, take time to understand, modulate the pacing of how one can move through time, and generate interconnections across time and in people's everyday lives. In particular, Odom et al. [52, 56] discuss eight key qualities of slow technology that further extend the concepts presented by Hallnäs and Redström [29], and these conceptual qualities have informed the core design qualities in the interactions for Queue Player. These qualities include *pre-interaction, implicit slowness, explicit slowness, temporal modalities, temporal interconnectedness, temporal granularity and density*, and *ongoingness* (**see** Table 1 **for abbreviated quality definitions**).

In designing Queue Player, we sought to enable a group of four friends to explore a shared archive of music accumulated over the lifetime of their Spotify accounts. We arrived at four as an optimal number of friends for our initial design of Queue Player because we were interested in exploring interpersonal social connections among a group (i.e., beyond a one-to-one relationship of two people). Less than four friends did not provide adequate diversity in terms of multiple people's perspectives and their listening history archives. Having more than four friends risked integrating too many people that could introduce challenges in field study logistics and in recognizing each person's unique perspective within the system. However, we see a clear opportunity to explore differing

Table 1: Brief Definitions of Slow Technology Qualities.

Slow Technology Quality	Definition
Temporal Modality	Different forms of time; can be linear or non-linear
Temporal Interconnectedness	Integrating two or more temporal modalities
Pre-interaction	Space and time prior to a moment of interacting with an artifact
Implicit Slowness	End-user control intentionally enables direct control of pacing
Explicit Slowness	End-user control is restricted, and pacing cannot be controlled
Temporal Density	Frequency of data entries, interactions, or events over time
Temporal Granularity	End-user 'tuning' of the amount of time to move through when interacting with an artifact
Ongoingness	Perpetual movement of time through an artifact

numbers and configurations of friends and loved ones in future research.

A central part of Queue Player's interaction design is the use of tap tempo as a *temporal modality* for song selection. Tap tempo is used as an alternative way for users to temporally interact with their Queue Players, by using time as an input interaction instead of as a way to modulate data output. We envisioned that tap tempo would also allow users to draw from their current experiences at the time of interaction (e.g., tapping faster tempos when exercising and slower tempos when preparing for bed). In this way, tempo, time of day, and people's routines would demonstrate *temporal interconnectedness*, and greatly influence how and when users interact with their Queue Players. Tap tempo also illustrates *pre-interaction*, as it only suggests a tempo for upcoming songs to be queued. With Queue Player, users would have no indication of which part of their listening history songs will be pulled from or the emotional quality the songs would have, as tap tempo merely probes users to ruminate on what is to come.

Another feature of Queue Player we implemented is that it displays a queue of songs to play for any given tempo. Once a user taps a tempo on their Queue Player, the queue lights change to reflect the user that tapped a new tempo as well as subsequent songs that match that specific tempo. A key aspect of this interaction is that the first song that shows up in the Queue always comes from the user who tapped the new tempo, and this design decision was informed by several qualities of slow technology. First, the queue lights would exemplify *pre-interaction*, as users wouldn't have any additional information about songs that will play apart from knowing which songs belong to which user(s), as well as which users have queued new tempos for the listening session. We anticipated this would prime users for changes that would occur while co-listening with other users and also offer opportunities for anticipation and curiosity for what kind of music will be played. Similarly, the queue lights might also give pause for users to reflect on what song will be played when they see their own songs in the queue—whether this is solely their song, or a song shared with other users—and at what point(s) in their lives they may have listened to a particular song. Second, if the queue is left untouched (i.e., no new tempos are added to the queue), users would have the choice to either let songs with the current tempo play until that tempo is exhausted, or they can tap a new tempo. Tapping would allow users to 'speed up' the rate at which they explore the collective listening history and manipulate the queue, and this decision was influenced by *implicit slowness*. On the other hand, once a user adds a new tempo to the Queue, they are restricted from adding another tempo until that song has been played and leaves the queue. We also developed the Queue Players to play songs completely, so users would have no control over how much time their tempo would sit in the queue. This design decision was informed by *explicit slowness*, with the intention of slowing down the rate at which music can be listened to. We hoped that this would give users time to reflect on the songs that are playing while their tempo is in the queue, and to intentionally consider what new tempo(s) they will tap before adding it to the queue.[2]

Given the likely vast combined music archive among four users, we chose to sort songs from lowest to highest tempo to manage *temporal density*, with tap tempo offering *temporal granularity*. With the rate of music consumption slowed down by restrictions to the queue and the requirement to listen to songs in full, we intentionally designed tap tempo as a way to mitigate the friction people might experience with the density of the archive. The *temporal granularity* of tap tempo allows users to effectively 'tune' the amount of time they spend exploring a specific tempo, so that they can have more flexibility in navigating a temporally dense archive of songs.

The integration of indicator lights to communicate which users are currently co-listening during the current listening session, was primarily influenced by the concept of social translucence, which Erickson et al. describe as quality for technologies that provide a 'social proxy' to "[support] mutual awareness and accountability" of others during a shared activity [14]. For Queue Player, it was important to incorporate this quality into the design so that users could feel the presence and be aware of their co-listeners, as well as feel a sense of accountability to interact with their Queue Players while listening alone or with others. In this way, the indicator lights further demonstrate *pre-interaction*, as they may prompt users to interact with their Queue Player and encourage them to co-listen if they are aware of others already listening.

Finally, to incorporate *ongoingness*, we chose to automatically move to the next slower tempo in the archive once a specific tempo had no remaining songs. This would allow users to continue an uninterrupted exploration of the collective song archive even if no new tempos were introduced.

[2]We encourage readers to view the short video archived as a supplementary material with this paper for a dynamic illustration of how the Queue Player system works.

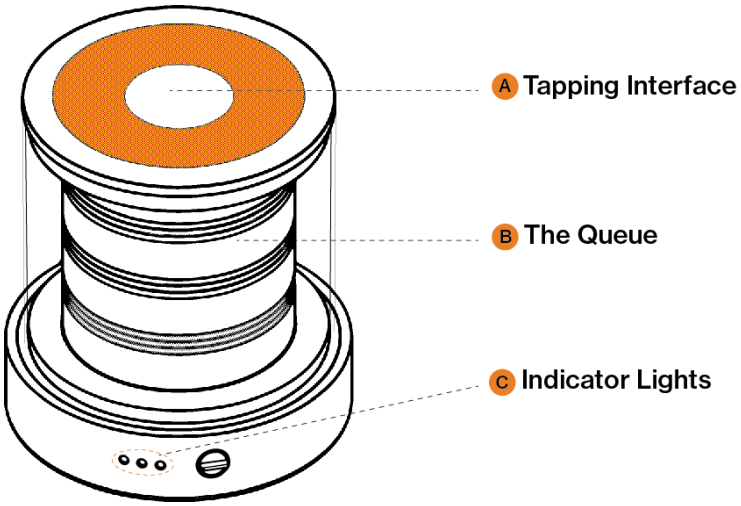

Figure 2: Queue Player key features: A) The Tapping Interface: Detects taps to establish a tempo for songs to be added to the queue; B) The Queue: Displays a queue of songs that are currently lined up to be played; C) Indicator Lights: Show which users are currently co-listening. See *Appendix F* for more in-depth descriptions of Queue Player features.

3.1.3 Developing Queue Player's infrastructure. Queue Player works by leveraging a combined archive of four people's Spotify music listening histories. We developed a Python script that communicates between a remote main server and four Queue Players for a synchronous listening experience between users. The Python script securely requests and processes songs from the combined song archive which are sorted into containers from lowest to highest tempo and retrieved via a tap tempo interaction on the user end. Once a user taps a tempo, the script requests songs from that tempo—or the next lowest tempo if songs at the requested tempo are not available—and a queue of songs at that tempo is formed. We designed the script to keep track of individual songs that were already played in their respective tempo containers to ensure the same song was not repeatedly played before those still unplayed. However, in outlier cases where a selected tempo was very low or very high, the limited songs available were more prone to repetition.

To enable song playback for each Queue Player, we used *Spotifyd* [99], an open-source Spotify client, to configure a Raspberry Pi 3B+, the microprocessor used for the Queue Players, as an official client that could interface with the Spotify API. Each Queue Player had a dedicated Spotify account to control song playback, allowing each device to play music independently and account for any latency and concurrency issues that might occur between the server and Spotify API once the Queue Players were deployed to separate households. To synchronize the Queue Players over distance, we configured the server to keep track of and indicate all users' active states, and broadcast the track IDs of the songs in the queue, the current tempo, the timestamp of the currently playing song, and the current state of the queue (including section colors and whether a user had tapped a new tempo) to all Queue Players.

3.2 Crafting a small batch of Queue Player Research Products: The Finalization Phase

We crafted a small batch of Queue Player *research products* to investigate how using a slow technology lens in the design of Queue Player features and interactions might shape people's music-listening experiences, social interactions, and reflections while co-listening with others. *Research products* are created to drive a research inquiry and have a high-quality finish such that people engage with them as is (i.e., a thing) rather than what they might become (i.e., a prototype) [60]. *Research products* are also meant to operate independently for substantial time periods to support long-term field studies in people's daily environments. Following prior work (e.g., [7, 57, 59, 62]), this approach is particularly well suited for supporting empirical studies of slow technologies because these design artifacts often take time to understand and require experiences and interactions to accumulate with them through time.

Regarding the form of Queue Player, we developed a cylindrical, drum-like form (**see** Figure 2) for two primary reasons: (i) a flat top would strongly suggest a tapping interaction and would invite users to tap various tempos to explore their music-listening histories; (ii) the flexibility of this form would allow users to view a queue of songs from any angle, opening up more potential areas for the placement of a Queue Player in people's homes. The decision to have Queue Player act as a lamp was also informed by the cylindrical form, as light would also be visible from anywhere in a user's living space. Indoor lighting has long been associated with mood, cognition, and prosocial behaviors [1, 9], with bright lighting in particular, having the potential to increase self-awareness, self-reflection, and public self-consciousness [16]. Fenigstein et al. describe public self-consciousness as "the tendency to be aware

Figure 3: Left to Right: All prototypes and design iterations made throughout the design process; Final components used in the finalized Queue Player research products (unassembled); Finalized, assembled Queue Player research products.

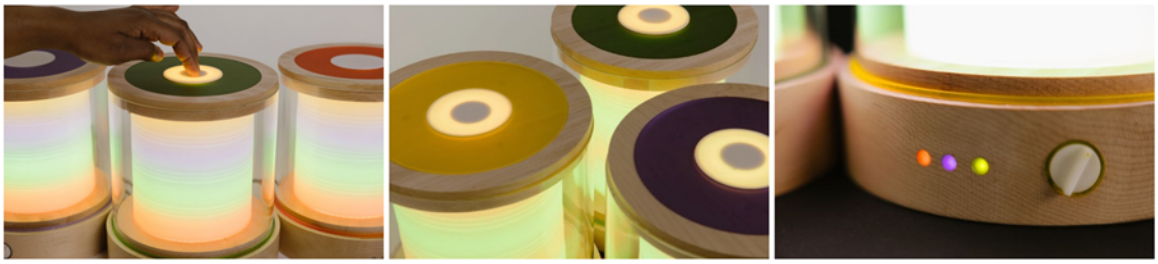

Figure 4: Fully implemented Queue Players and their features from Left to Right: The queue; the tapping interface; indicator lights.

of oneself as part of a social context" [17], a quality that was crucial for encouraging reflection on one's listening history during co-listening.

It was essential to use robust materials for the Queue Players so that they could withstand long-term tapping from users. Through various material explorations after Queue Player's form was determined, we decided to use a clear acrylic tube as an outer shell for the Queue Players and a white resin printed diffuser, as this gave better light resolution while also adding translucency to the queue. This translucency of the queue lights mapped to the theoretical concept of *social translucence*, which would provide a minimal amount of information about a user (i.e., their ownership of a particular song) while still indicating their presence in a specific part of the collective song archive. Social translucence was more explicitly implemented with small LEDs on the base of each Queue Player, to indicate which users were actively co-listening. Inspired by the slow technology proposition of creating technology that *requires time to understand* and related work on ambiguity [23, 24], the aim of these decisions for communicating social presence was to use minimal information to catalyze a range of experiences that can evolve as one develops a sensibility for navigating their listening histories through Queue Player.

Other materials used for crafting the finalized Queue Players include CNC-milled maple wood for a wooden base and top, resin and 3D printed inserts, and laser cut frosted acrylic (**see** Figure 3). The long-lasting qualities of these materials further helped to construct a robust and refined product for our field deployment. The finalized hardware implementation of the Queue Players includes a piezoelectric vibration sensor for detecting taps, an Adafruit Digital RGBW NeoPixel LED strip (for the queue) and ring light (to communicate the current tempo), a HiFiBerry DAC+ RTC board for RCA output, and small LEDs (indicator lights), which were all integrated with a Raspberry Pi 3B+ to complete the hardware implementation.

3.3 Queue Player Field Deployment Study: Participants, Data Collection, and Analysis

After completing the small batch production of four networked Queue Players (**see** Figure 4), we recruited 4 participants (**see** Table 2) living in a large city in Western Canada, to participate in a 6–week field study for Queue Player (we use pseudonyms when referring to all participants in this paper). Similar to the aim of the original Technology Probes paper [34] and several field studies since then [22, 57, 59, 65], we initially focused on a small group of participants to gain a rich, descriptive understanding of the research space to inform what might be salient issues for future research and practice.

Queue Player was designed to enable co-listening among close friends or family living apart, and we recruited a friend group who knew each other well and had established relationships that could facilitate deeper and more meaningful interactions during the study. Taking inspiration from the anthropological research method of 'deep hanging out' [35, 68, 87, 100], we ensured that the participants selected were also people that the FA (First Author) knew to so that there was familiarity among the entire group. Thus, recruitment for the study was conducted through word of mouth. The participants regularly spend time together, have been friends for at least 6 years, and have all known the FA for approximately 2.5 years. The intent for Queue Player to be used by close friends and loved ones to explore how their collective music listening history archive might

Table 2: Participant Profiles

Participant	Florence	Julian	Gregory	Kassandra
Age	Early-20s	Early-30s	Early-30s	Late-20s
Gender	Female	Male	Male	Female
Living Environment	House with her parents	Apartment with one roommate	Shared house with his landlord	Apartment with one roommate
Approx. Age of Spotify Account	6 years	10 years	5 years	6 years
Individual Songs Owned in the Shared Archive	20,537 songs	8069 songs	23,122 songs	14,542 songs
Placement of Queue Player in Home	Bedroom	Living Room	Bedroom	Living Room
Use of Queue Player in daily life	Use in the evenings after coming home.	Use in the evenings after work; Usually playing in the background while talking to his girlfriend on the phone.	Use when home and has free time.	Use in the evenings after work, often while cooking and doing other mundane tasks.

operate as a resource for supporting co-listening, social connection, and interaction, led us to recruit participants who knew each other well, had a history of shared social experiences, and were comfortable in sharing and listening to music together. However, it is important to acknowledge that members of social groups that are less familiar with each other or which have highly heterogenous tastes in music may produce different results, marking a clear area for future research. All of our participants had Spotify Premium accounts spanning at least five years (**see** Table 2), to provide a rich and diverse database for Queue Player to draw from. It is important to note that due to our participants' pre-existing interest in using Spotify, they likely already had some interest in exploring past music tastes and trends.

Before conducting the study, we asked each of the participants to request their 'Extended Streaming History' [101] from Spotify, which includes all of the songs that a user has listened to during the lifetime of their Spotify account. In total, the combined archive for the Queue Player study included 66,270 unique songs in the archive (which is approximately 3313.5 hours or 138 days' worth of continuous listening).

During the study, we aimed to collect descriptive accounts from the participants about their experiences with their Queue Players over time, both individually and as a part of the group. During an initial visit to each participant's house, we provided them with a Queue Player, external speakers (for audio output) and a field study booklet that included instructions and prompts for how they might use the device throughout the study. After installing and demonstrating the Queue Players, the FA conducted an introductory interview to gain an understanding of what participants' past and present listening habits were like, their thoughts towards collecting and having a tangible form of their Spotify listening data, and their thoughts towards experiencing their listening histories combined with three of their friends' histories. Participants were encouraged to develop their own understanding and sensibility towards living and interacting with their Queue player, giving them the freedom to engage (or not engage) with the device as often as they chose (**see** Figure 5).

The FA then conducted weekly listening sessions over the course of 4 weeks and visited one participant's house each week. For each session, the FA probed each participant to get a sense of their experience with their Queue Player both on an individual level and as a part of the group. These sessions were audio-recorded and lasted anywhere from 60–90 minutes. All recordings were saved confidentially to a secure cloud storage. During each session, the other three participants also listened on their ends simultaneously. After each listening session, field notes were taken with impressions, key quotes, and notable moments observed during the session. While these instances were recorded, participants also used their Queue Players outside of the listening sessions and continually lived with and integrated them into their daily lives and routines (**see** Table 2).

During the final week of the field study, we conducted a final group interview with the participants. This interview focused on their reflections on the study, experiences using Queue Player, feelings towards co-listening and a shared exploration of their listening histories, and considerations towards design alternatives and future design work in this research and design space. During this session we often referred to fieldnotes and recording transcripts that captured participants' earlier experiences to explore possible changes in their individual and collective attitudes toward Queue Player over time. At the conclusion of the study, participants were compensated $100 for their time and participation; we also made and gifted them each a zine that illustrated the overlaps and connections between their Spotify listening histories (**see** Appendix E).

All interview sessions were audio recorded and transcribed. Researchers took field notes during each interview. Field notes were

reviewed immediately following each listening session and interview, and tentative insights were noted in reflective field memos [25]. Analysis of the data was an ongoing process and after each visit to participants, we conducted a preliminary analysis, searching for emergent, stabilizing, and shifting patterns across our data to draw out underlying themes [51]. The listening session and interview transcripts were then coded by two members of the research team, using a hybrid approach involving first deductive and then inductive coding. With inductive coding, we examined the participants' interview transcriptions without predefined categories, identifying key quotes and forming themes based on recurring ideas. For deductive coding, we applied predefined categories, such as "perceptions of Spotify data" and "perceptions of slowness" to identify quotes and data that fit these existing themes. We held weekly meetings that lasted 2-4 hours over a six-week period to review and discuss themes in our analysis. We also created affinity diagrams to model connections and differences among participants. Ultimately, this process yielded five main themes: *attuning to early anxieties*, *re-encountering listening history data*, *developing and acting on social awareness of others*, *unique uses*, and *adjusting to slow technology*.

4 FINDINGS

Next, we present examples and observations taken during the field interviews that best help to illustrate the themes in our findings. These findings focus on how Queue Player mediated co-listening experiences between participants, as well as intimacy, reminiscence, serendipity, curiosity, and anticipation. They also touch on experiencing one's data, and the implications of these experiences on an individual and social level. Lastly, they demonstrate how the established relationships between participants helped to inform some of their experiences with their Queue Players, and shape considerations for future interactions with digital music and personal data.

4.1 Attuning to Queue Player: Adjusting to Early Anxieties Over Social Disclosure

When the FA first invited participants to join the Queue Player field study and explained its details, each of them exhibited some level of apprehension towards the lack of control over the music Queue Player would share from their portion of the collective archive. This apprehension also emerged during initial interviews, where participants shared anecdotes about how various life experiences influenced both their music tastes and attitudes toward music sharing. However, these anxieties were soon alleviated, and participants were able to focus on their data in itself.

One of the key goals of this study was to examine how people might perceive their data once it is presented to them in a physical form in their everyday lives. Queue Player allowed participants to 'have' their data while it was once intangible and inaccessible. By relinquishing some control over song choice to Queue Player, participants could shift their thinking away from anxieties about disclosing their music and critically reflect on what their data ultimately says about them. Participants were also able to adjust to disclosing their music as they developed more familiarity, trust, and understanding of each other throughout the study.

4.2 Re-encountering Listening History Data

4.2.1 Experiencing Nostalgia and Contextualizing Listening Data. During initial interviews, the FA asked participants what their thoughts were on experiencing their data again through using Queue Player. **Kassandra's** response nicely summarized her past experiences and how they could impact encounters with her data while using Queue Player. She anticipated that her experience would be similar to her existing music listening practices with revisiting playlists:

> "I've looked a few times at old playlists that I've made that I never reach for anymore, and it's definitely like time travel. I think that's one of the most magical things about music. It can take you back to a place or memory of when you first heard that song, or when that song sort of meant something to you. [...] What year was that? What kind of headspace was I in?"

After the study concluded and she had lived with Queue Player for considerable time, there was a noticeable shift in how she reflected on songs she had listened to in the past:

> "I think initially as some songs came up from a long time ago, I would recall that period of life and what it felt like, but because things are different now, I was able to listen from a different headspace. I could still enjoy it but maybe just in a more present way rather than reflecting on the past."

Queue Player enabled her to consider how meaningful her listening history is in the context of who she is today, and the life experiences between initially hearing that song and re-encountering it in the present. This shift in reflection also highlighted how revisiting

Figure 5: Participants using their Queue Players, Left to Right: Orange Queue Player in Kassandra's living room; Green Queue Player in Julian's living room; Yellow Queue Player in Florence's bedroom; Violet Queue Player in Gregory's bedroom.

music from one's past can evolve from being a purely nostalgic experience to a more integrated part of one's current identity. Queue Player not only facilitated nostalgia but also helped participants contextualize their listening histories, providing a deeper understanding of how past and present selves are connected and how that impacts current individual and social music-listening experiences.

4.2.2 Reflections on Authenticity and Completeness of Listening Data. Before beginning the study, we asked the participants to request their extended streaming histories from Spotify to create the song database that the Queue Players would pull music from. However, they were unaware that their data could be requested. This revelation opened up opportunities to probe participants about their experiences with now 'having' their Spotify data in a tangible and easily accessible form. All participants had ideas and expectations about their data. For example, Florence shared an initial sense of confidence in what she would find in her data:

> "I think off the bat, I'm already a very cautious listener. So, I feel like if I were to see my data, I wouldn't be surprised."

Kassandra, however, had less confidence anticipating the breadth of songs that might appear in her personal data, in part due to algorithmic interference:

> "Sometimes songs will come up accidentally, or the next song would be on Spotify radio. So, that does make me nervous. I don't know [what's] gonna come up."

Across listening sessions, it was common for participants to question their data—its origin, authenticity, and their identities reflected through the music played with their Queue Players. In **Julian's** listening session, his reflections on his data pointed towards 'imperfections' and 'impurities' in the archive, as he recalled people sometimes borrowing his Spotify account. He further speculated on the origins of the unfamiliar songs in his data:

> "[For] many of the songs that came up for Kassandra, I felt like it was music I knew she'd probably listened to before. And for Gregory, I felt like many of them made sense [. . .] But for my own music, often, I did not recognize a song that was associated with me, which was weird. I think it could be because there are some songs that Spotify suggested, or maybe I listened to a playlist that Spotify made, or I heard it like once, or maybe heard a portion of [a song] and then skipped it, but it was still in my history."

The other participants also had similar experiences throughout the study. Florence shares her Spotify account with her family and often mentioned certain songs belonging to her brother or dad. In his listening session, Gregory also recalled having friends use his Spotify account during road trips to play music as he drove.

These moments of reflection while re-encountering listening history data showed that each person's listening data was an amalgamation of choices and listening instances that weren't solely theirs. **Julian** summarized this well during the final group interview:

> "We kind of recognize what we think is our music. [. . .] If it is certainly stuff from our accounts, and especially if it's stuff that we've played because we've clicked on it, not because Spotify has played it for us without us remembering it, then that's really interesting because that says something about us not recognizing our own music. We're having a different perception of what our music is relative to what it actually is."

When designing the Queue Players, we only considered using Spotify to extract each person's listening history data due to its prominence and ease of interfacing. However, frictions participants had surrounding the authenticity of their histories and the incomplete picture their histories painted for them as individuals and as a part of the group soon shifted as the study went on. Towards the end of the study, participants were able to realize the impossibility of having a completely 'authentic' and 'perfect' dataset by holistically reflecting on their listening experiences and the life experiences surrounding them.

4.3 Developing a Social Understanding of Others

4.3.1 Uncovering Deeper Connections Through Slowness and Presence. As the study progressed, participants were able to better understand themselves and each other both through the music being played, and through design qualities in Queue Player.

The explicit slowness of song duration and the Queue Players' requirement for songs to be played to completion was initially a barrier participants needed to break through to truly develop an understanding between and of each other. All of the participants expressed a desire to skip ahead to songs that better aligned with their preferences, or to traverse the archive much faster than they were (exemplifying implicit slowness through tap tempo navigation). However, as the study continued, explicit slowness also provided opportunities for broadening music tastes and a better understanding of others.

It also prompted participants to think more deeply of each other and consider how their music was significant to their life.

For example, **Kassandra** shared her experience with listening to Gregory's music, and subsequently experiencing empathy with Gregory's experiences, an appreciation for music from a different culture, and an experience with songs that were different from what she would typically listen to:

> "I think it's changed the way that I think about songs. In specific, [. . .] let's say I'm listening to one of Gregory's songs, and it's like K-pop or something in a different language that I don't really know. It kind of makes me feel like I try to put myself in his shoes. Just given his personality and what I know of him, like what does he like about this? Because we listen to music because it makes us feel something. And so, I'm like "what does he get out of this?".

During the final group interview, **Julian** shared his experience around having an awareness of others and how social co-presence further helped him to understand others and their routines while observing his Queue Player:

> "I definitely liked the shared experience of it because you can see when other people are listening, and it also gives you a little bit of information about their life and their schedules. Like "this is when they tend to listen to music, or [this is] when they're home." That's cool that you can infer that."

Queue Player enabled participants to have an explicit awareness of others and their listening habits through the queue, and a peripheral awareness of each other through the indicator lights which, over time, appeared to have a synthetic effect. These combined qualities instilled a sense of intimacy and allowed the participants to learn and understand various things about each other that they may not have known otherwise.

4.3.2 Alternative Outcomes and Experiences Through Queue Player Affordances. Queue Player's affordances led to a range of interpretations from participants. For example, **Gregory** outlined his understanding of participants through tempo:

> "There is a point where, because of how Queue Player [works], it could be putting [people] in a box that fits a particular profile. It [could be] because of the [amount] of music I listened to, or other people listened to at a particular tempo. So, it could misrepresent them a little bit so when you listen to a particular tempo, you could be like "Oh, that's Gregory, or Florence, or Julian, or Kasandra."

This highlighted the inevitability that although Queue Player allows exploration of the group's song archive, the participants were still limited to different snippets of each other's listening history. This did not necessarily show a 'true', objectively perfect', or 'authentic' reflection of each participant's music taste or listening habits.

During the final group interview, **Gregory** also shared an anecdote about how his songs that came up in the queue were pre-judged by another participant because they got to know what a portion of his listening history looked like:

> "There was one time [the queue] was like all purple. Then as soon as that happened, somebody tapped immediately. So, there was a feeling where I was like "Oh, perfect; It's all my songs. That's bad."

The *pre-interaction* of participants viewing the queue often led to instances of anticipation, and assumptions of what would play based on what they previously heard and experienced from certain users resulted in experiences like Gregory's as the participants developed a better understanding of each other and became attuned to each other's music. Implicit slowness informed the decision to use tap tempo to speed up the rate at which the song archive could be explored. Tapping a tempo overrides all songs in the queue at the current tempo once a song at the new tempo reaches the top of the queue, and participants often used this as an improvised workaround to 'skip' songs in the queue that they didn't want to hear. This was an example of how participants were able to create new ways of experiencing and interacting with their Queue Players through tap tempo, despite minimal interaction options. Gregory's reflection on being "profiled" by his music highlights an interesting dynamic: while music sharing can deepen understanding and empathy, it can also lead to assumptions and shape expectations about shared data.

4.3.3 Social Awareness and Care of Others. Throughout the study, participants shared their experiences with social translucence and how having a subtle awareness of each other influenced their use of Queue Player. They expressed that knowing when others had their Queue Players on encouraged them to co-listen as well. **Florence** illustrated this during her listening session:

> "If someone's on then I do it too just because it feels like "oh, we're sharing this experience together". Like, we're not together but I feel like we're together."

Participants shared in this sentiment, and their appreciation for each other's presence was evident during listening sessions. However, participants also expressed how having an awareness of when each person was co-listening influenced how they would interact with their Queue Player, particularly in exploring the archive.

Florence and Gregory both shared that they were more passive listeners than Julian and Kassandra, and that they often chose not to introduce new tempos to the queue while others were co-listening. In Gregory's case, his interactions with his Queue Player were contingent on everyone listening. For **Florence**, she shared that continually landing in the same part of the archive during group listening sessions motivated her to interact more with her Queue Player:

> "[Before] I was more like, "oh, I'll just let other people tap" . . . But then the situation we have now where it's like, we're listening to the same song forever, I would find myself interacting more [. . .] than in the beginning."

This shift in Florence's thinking and behavior over time presents implications for co-listening as a group and considering the impact of individual listening practices on the group's overall listening experiences. **Gregory** also shared specific instances where he chose not to interact with his Queue Player out of concern for potentially disrupting others:

> "Usually when I [turn on] the Queue Player, I don't like slow music. But it could be that at that particular time, what [another participant is] doing is they're actually meditating or something."

These reflections highlight how Queue Player enabled Gregory to empathize with what others might have been doing or experiencing with their Queue Players at the time, prompting him to consider their needs over his preference for faster tempos. It also demonstrates how the social dimensions of Queue Player influenced people's experiences over time, as well as how and when they chose to interact with their Queue Players.

4.4 Novel Uses of Queue Player in Everyday Life

One of the primary goals of the Queue Player study was to explore how a temporal interaction modality like tempo could facilitate different experiences such as anticipation, intimacy, and social bonding among co-listening. **Florence** described how during a previous listening session, her Queue Player helped to regulate her emotions, but also roused her into a more upbeat activity:

> "I think at one point, it was just a lot of like, slow music. And so, I was doing a very slow activity, and I think my mood kind of catered a lot to what I was doing [...] And then it changed the tempo [. . .] And I felt compelled to be like, "Okay, I gotta do something else". I couldn't do this silent activity anymore [. . .] It didn't make sense for me to keep doing that."

Florence's account highlights how tempo and song dynamics can shape emotional and behavioral responses during co-listening. In this instance, the emotional qualities of others' music were able to influence Florence's personal listening experience. Although emotional interpretations of songs may have varied among the participants as songs played, this example also demonstrates Queue Player's potential for creating opportunities for social bonding, mirroring activities, and intimacy between co-listeners during instances of shared emotional perceptions.

While existing means for social music sharing offer limited control over tempo variability, **Gregory** shared a reflection on how Queue Player acted as a unique grounding element for him by providing direct control over the tempo of songs being played in a social context to address ailments from his tinnitus:

> "I have tinnitus. . .I think that's I think that's why I like the higher beats. Because that's one way to live with tinnitus; it's that you have higher beats to drown out the ringing."

While participants mostly explained how Queue Player allowed them to connect with each other, and to learn more about themselves and each other, Gregory's account illustrates a unique and personal benefit. His experience highlights tempo as a focal point in Queue Player's design, and how it helped to establish a sense of calm and relief from his tinnitus. The alignment of tempo with his personal needs also created an environment where he could fully immerse himself in the listening experience, and experience moments of anticipating similar fast-paced songs while using his Queue Player.

4.5 Adjusting to Slow Technology

During initial interviews with participants, they all reflected on how their music listening habits evolved over the years. **Kassandra**, for example, described her journey from listening to music through analog music media like CDs in her childhood, to digital music in her teenage years and adulthood. She noted a significant shift in her approach to discovering new music:

> "I would say, interestingly enough, with the increase of accessibility there's a decrease in slowness and meaningfulness perhaps, and intentionality. Before, it was more waiting and curiosity. Versus now it's a little bit more like, right off the bat, I need to know within the first 15 seconds of the song, whether or not I like it. Because there's so many songs to listen to."

Kassandra's observation notes that the vast amount of songs now available to users on music streaming platforms presents a tradeoff with the more reflective qualities of older music-listening media. It also highlights the potential slow technology has to reinstate opportunities for experiencing anticipation and curiosity and counteract the immediacy of modern digital music platforms. This insight aligns with one of the goals of the study, which was to explore how integrating slowness into music technology could facilitate ongoing experiences with co-listening.

A core aspect of Queue Player's design is the balance between implicit and explicit slowness. Implicit slowness enabled 'speeding up' exploration of the archive through tap tempo, while explicit slowness required users to wait for songs to play to completion before a new tempo could take effect. Before the study, participants were unfamiliar with slow technology, and the integration of implicit and explicit slowness resulted in frictions as they adjusted to the novelty of Queue Player. During his listening session, **Julian** expressed frustration with slowness embedded in the design:

> "There's been a few songs where I really wanted to know what a song was, but I think Shazam didn't know and I wasn't able to tell; I found it really frustrating. [. . .However,] It could be distracting focusing on what the band is and looking it up. Whereas here you kind of have to live with it and more so enjoy the moment."

Participants also experienced moments of serendipity and realized that slowness could reveal more about music than they initially thought. During the final group interview, **Julian** elaborated on how his experience with slowness impacted his views on exploring music via streaming platforms:

> "I think with being able to just change songs whenever we want, we tend to not experience the exposure of songs that we don't like, because if it's not interesting, we're just like, I'm just going to skip it. Whereas [with Queue Player] you're forced to be exposed to songs that [you] usually wouldn't listen to, for better or worse."

During our final group interview, **Kassandra** also gave a summative reflection on slow technology based on her observations during the study:

> "I think in this day and age, we're [a] really fast paced, busy, busy, busy culture. Creating a product that can kind of counteract that, I think, is actually important. Because a lot of technology nowadays is moving forward in the same trajectory to make our lives easier, [and] more enjoyable."
>
> [. . .] When you create something that forces you to change your routine, even if it's just as simple as like the lack of buttons, or lack of control, it disrupts something[...] And there were moments [with Queue Player] where I was like [. . .] I want to skip the song. Or like, I want to turn down the volume, or I want to do something to change [the tempo]. But even if I were to change the tempo, I'd still have to wait."

Together, these accounts illustrate how Queue Player's integration of slow technology prompted participants to reconsider their relationship with music, fostering deeper engagement, patience,

and a heightened appreciation for moments of anticipation and presence in their listening experiences.

5 DISCUSSION

As the capabilities of music streaming services evolve, new opportunities emerge as people's listening habits accumulate into large historical archives. Our work offers new insights into the reflective potentialities of socially combined personal histories among loved ones when made distributed and materially present with tempo as a central modality for interaction. Our findings suggest rich possibilities for people to revisit their listening histories through co-listening with those they already share a close relationship with. Our work builds on Odom et al.'s extension [56] of the original, highly aspirational slow technology design qualities [29], and offers new insights into how designing for co-listening through a slow technology lens can be integrated into design practice. By examining the shared musical experiences and reflective processes of participants with Queue Player, we found renewed potential for deeper social connections and personal insights through the collective exploration of music archives. Next, we present considerations for HCI and design communities that emerged from our work.

5.1 Designing for Data Autonomy and Long-term Interactions

Queue Player combined four distinct and unique listening histories between friends into one collective social archive. Initially, participants experienced early anxieties over the potential social disclosure of their combined listening histories, and the lack of control over song selection. This anxiety was rooted in concerns about how their personal listening history data might be perceived by others. Participants' apprehensions suggest that prior knowledge of their data outside of a social context might have lessened the anxiety felt when Queue Player surfaced their songs. On the other hand, introducing their data in this way prompted anticipatory and curious listening experiences, and open dialogue surrounding data authenticity and transparency. This indicates potential for future research to explore how both synchronous and asynchronous experiences and interactions could be designed for combined social data archives. For example, having an option to toggle between individual (asynchronous) and social (synchronous) listening modes with Queue Player could have provided familiarity and control, and potentially be scaffolded to reduce initial tensions while still expanding and sustaining experiences of anticipation.

At the beginning of the study, participants were also unaware that they could request their data from Spotify. Our work offers insights into how tensions with data recognition may be alleviated. By providing a tangible device for participants to 'have' their listening history data, this encouraged them to reflect on it more critically and extensively. Co-listening via Queue Player enabled participants to consider their data in relation to their friends', which opened new ways to experience, interact with, and reflect on their listening histories – both individually and socially. Relinquishing some control over song selection to Queue Player eased well documented tensions around the *burden of choice* [42, 46], while fostering discussions about future listening habits.

Queue Player's design also highlighted the importance of data autonomy. Participants' increased awareness of their listening history data suggests that giving users more control and transparency over their data may lead to deeper reflections and sustained interactions. In this way, our work offers a case that extends recent research that emphasizes the value of intervening technologies that can 'break data free' from their restrictive platforms in the service of encouraging situated experiences of reflection and mindfulness over longer time periods [61, 62, 84–86].

Moreover, the long-term interactions facilitated by Queue Player underscore the potential for sustained engagement with personal data. By regularly revisiting their collective listening history through co-listening, participants better understood the social dynamics around their musical tastes. Intertwining implicit and explicit slowness in the pacing and control users had with Queue Player offers a new strategy for future design work to encourage intimacy and social bonding in shared data experiences. For example, explicit slowness provided participants with time to understand songs and reflect on their significance to others. With implicit slowness, participants were able to adjust the pace at which they explored the archive through tap tempo and explore alternative trajectories through their data. We also observed how tap tempo encouraged shared agency and enabled participants to bond and collaborate to get the queue to a place of mutual enjoyment.

By integrating implicit and explicit slowness, participants were able to develop deeper, potentially more intimate, understandings of each other. In this way, our work offers a novel example demonstrating and validating how integrating implicit and explicit slowness design qualities can be mobilized as a strategy to support intimacy and social bonding in future research and practice.

5.2 Navigating Personal History Data with Tempo

We chose to use tempo as the central interaction modality for navigating the song archive for several reasons. First, it was an underutilized and novel form of time already bound to each song in the database. While prior HCI research has leveraged timestamp metadata for re-encountering personal histories (e.g., [6, 8, 54]), the use of tempo with Queue Player introduced more dynamic listening experiences and diversity between songs. This diversity also helped to better reveal social dynamics between participants. Timestamp metadata places users at specific moments in time, prompting reflection on their experiences during those periods. Tempo, however, extends this by facilitating reflection on both past experiences and new interactions with personal history data. Participants were able to explore their music listening histories in a non-linear and engaging manner, creating opportunities for anticipation and serendipity, as participants navigated the archive in unpredictable ways. Tempo also enabled a unique distribution of different parts of each participant's past and their music identity across the archive. This led participants not only to serendipitous musical experiences but also to a deeper understanding of each other in varied contexts.

Second, although organizing the combined database by tempo separated songs from chronological connotations specific to each

participant, it offered insights into how tempo can impact an individual's feelings, lived experiences, and activities performed while co-listening. This suggests potential for future research to explore how alternative temporal modalities could enrich user interactions with personal and shared data and still enhance feelings of agency by enabling unique experiences for each user, even in co-experiences.

Third, our findings point to new opportunities for extending prior research [38, 70] on the interconnectedness of tempo, dynamics, and emotion. For example, **Gregory** often expressed dislike and disinterest with slower tempos, while other participants, like **Florence**, embraced their influence for mood and activity. This suggests that tempo can function as a unique temporal modality, not only for navigating personal and shared music listening histories but also as a subtle yet expressive lens for revealing fluctuations in emotional presence, reactions, and engagement during co-listening. So, we ask: how might shifts in tempo and song dynamics shape the emotional contours of a co-listening experience, prompting moments of alignment, tension, or reinterpretation of music among listeners?

Lastly, the use of tempo prompted discussions around other temporal modalities. During our final interview **Julian** expressed a desire for having more temporal context around songs and having "different months or weeks where [Queue Player] plays music that [participants] all listened to at a common time of [their lives]". This desire for *temporal interconnectedness* points to an opportunity for future research to combine tempo with different timeframe modalities to pinpoint precise moments in an individual's life. Because tempo shaped the archive and allowed participants to land in unpredictable spots of their histories, providing even more granularity by contextualizing their songs through time could have led to more reminiscence on individual experiences during shared time periods. There are clear opportunities for future work to investigate how integrating different temporal dimensions, such as day, month, year, and even seasons, might further shape the contextualization of listening histories, and potentially lead to richer or more nuanced discussions around music, shared experiences, and individual experiences in a social context.

5.3 Integrating Comprehensive Personal Data Histories

During the field study, participants noticed 'dark spots' in their histories, where some songs were notably absent or were not attributed to them in the queue despite having listened to them previously. This highlights how personal history data can promote reminiscence, with a broader implication for managing expectations around personal data. At the beginning of the field study, participants shared how their relationships with music evolved with the emergence of new music-listening technologies. They also emphasized how their listening histories and personal memories were tied to other platforms outside of Spotify. This suggests that when designing experiences around combined histories, multiple platforms can be considered and integrated to better represent each person and their personal history. While it is impossible to exhibit complete histories on any single streaming platform, combining sources in research and design practice may be a step towards filling voids left in personal data histories. Last.FM [102] is an excellent example of an aggregator that already attempts this, yet it is still incapable of portraying a fully comprehensive and accurate archive to its users.

However, integrating multiple data sources poses challenges for future research and practice. The complexities of data heterogeneity—distinct variations in data—become apparent as different platforms and media for data collection have their own metadata, structure, and context. Each of these platforms can offer unique and deeper insights into people's histories, and designers and researchers can leverage more advanced data processing techniques and machine learning algorithms to synthesize the diverse data provided by each platform. This could help to create a more comprehensive and contextually rich representation of individuals' listening histories when combined with others'. We also see similar implications for other types of personal data, such as digital photographs or audio recordings, that become diffracted across different media platforms over time.

Throughout the study participants experienced the fragility of data histories, and the unlikelihood of maintaining completely 'pure' or 'complete' datasets. However, experiencing their data in this way enabled the exploration and contextualization of their data across time. It also enabled reflection on different life experiences in a manner that traditional music streaming could not have afforded. **Gregory's** reflection on music profiling also points to the individual and social expectations of each person's data in a social group, and assumptions that the data is completely curated by each individual alone and data history is a comprehensive reflection of its owner. This suggests an opportunity for future work to create a balance between surfacing more comprehensive data histories and contextualization of data.

Following recent work on designing and living with data (e.g., [13, 21, 44, 69]) and insights from our study, we see that there is room for new design initiatives that acknowledge and embrace the impossibility of personal data – and one's history bound up in it – being perfect, authentic, or objective. Such future initiatives may help people more readily engage with systems that mobilize individually combined personal data in shared data experiences and calibrate expectations of and for their data. Through the field study, our participants came to realize that people's personal data is not originally created to be revisited and combined with others' histories. However, its existence lends itself as a material that can be mobilized in future design research and practice for creating both individual and collective experiences for social connection and reminiscence with data.

6 CONCLUSION

We designed, implemented, and studied Queue Player to investigate how this system might enable co-listening experiences that foster social presence, interaction, and reflection, and to empirically explore conceptual propositions related to slow technology. Our findings reveal how mobilizing tempo as the cornerstone of interaction, combined with qualities of slow technology and social translucence, came together as a synthetic experience for our participants that supported diverse experiences of co-listening and revisiting one's listening history, encouraged social bonding, and evoked feelings of anticipation and curiosity that were envisioned

to scale over time. They also demonstrate the value that can come from making digital listening history data materially present by transforming it into a dynamic resource for interaction and, in this, supporting open-ended co-listening experiences. Collectively, our work contributes new opportunities for the HCI community to advance distributed co-listening technologies and experiences, as well as take a step towards understanding how slow technology could be further explored through an extended frame that combines different qualities of slowness and temporality. On a broader level, our work targets calls in the HCI community for outcomes that contribute to longer-term programmes of design research [49, 67, 81]. Ultimately, we hope this research supports future initiatives in the design and HCI communities aimed at inquiring into the complex and evolving social dimensions of human relations with each other and with technology over space and time.

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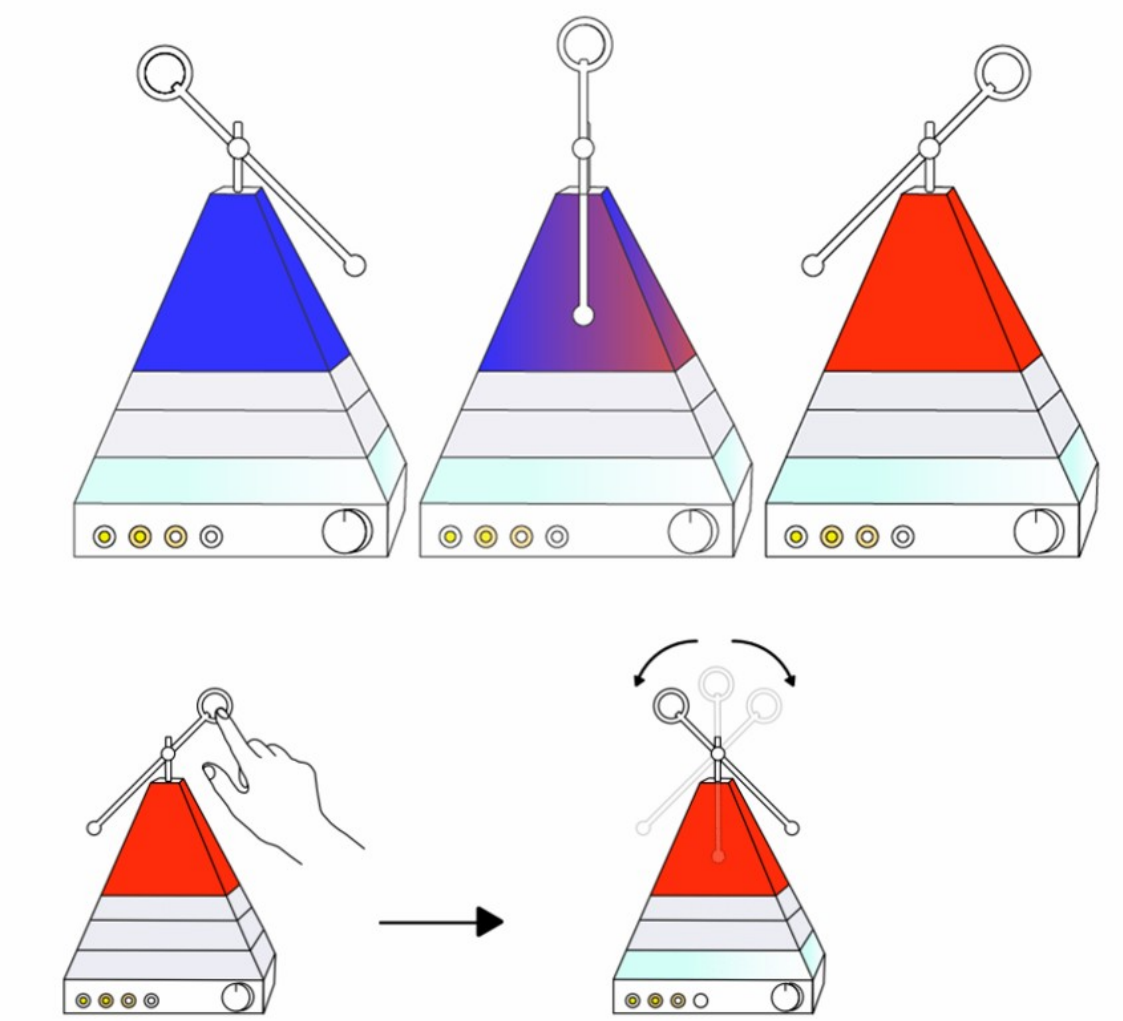
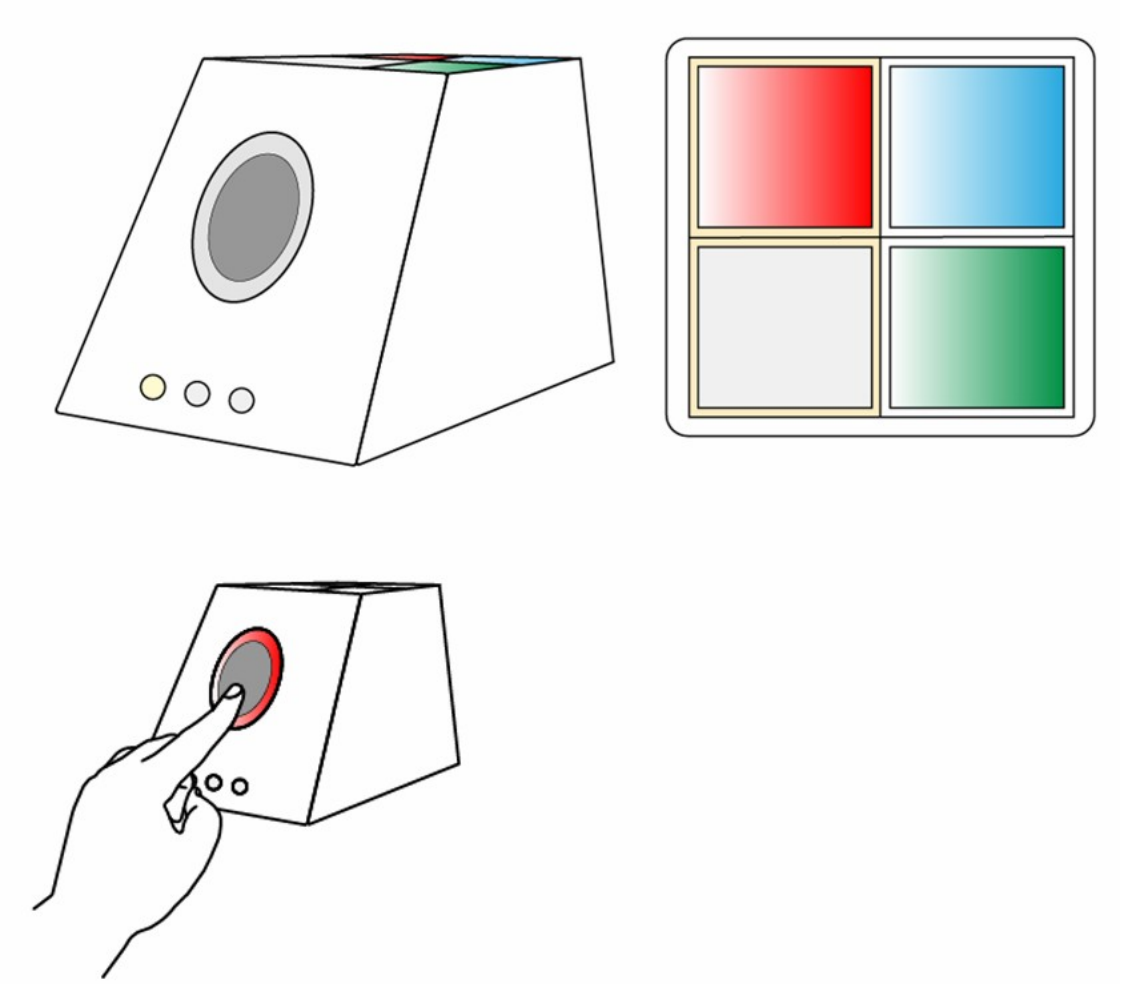
APPENDICES

A Metronome Queue Player



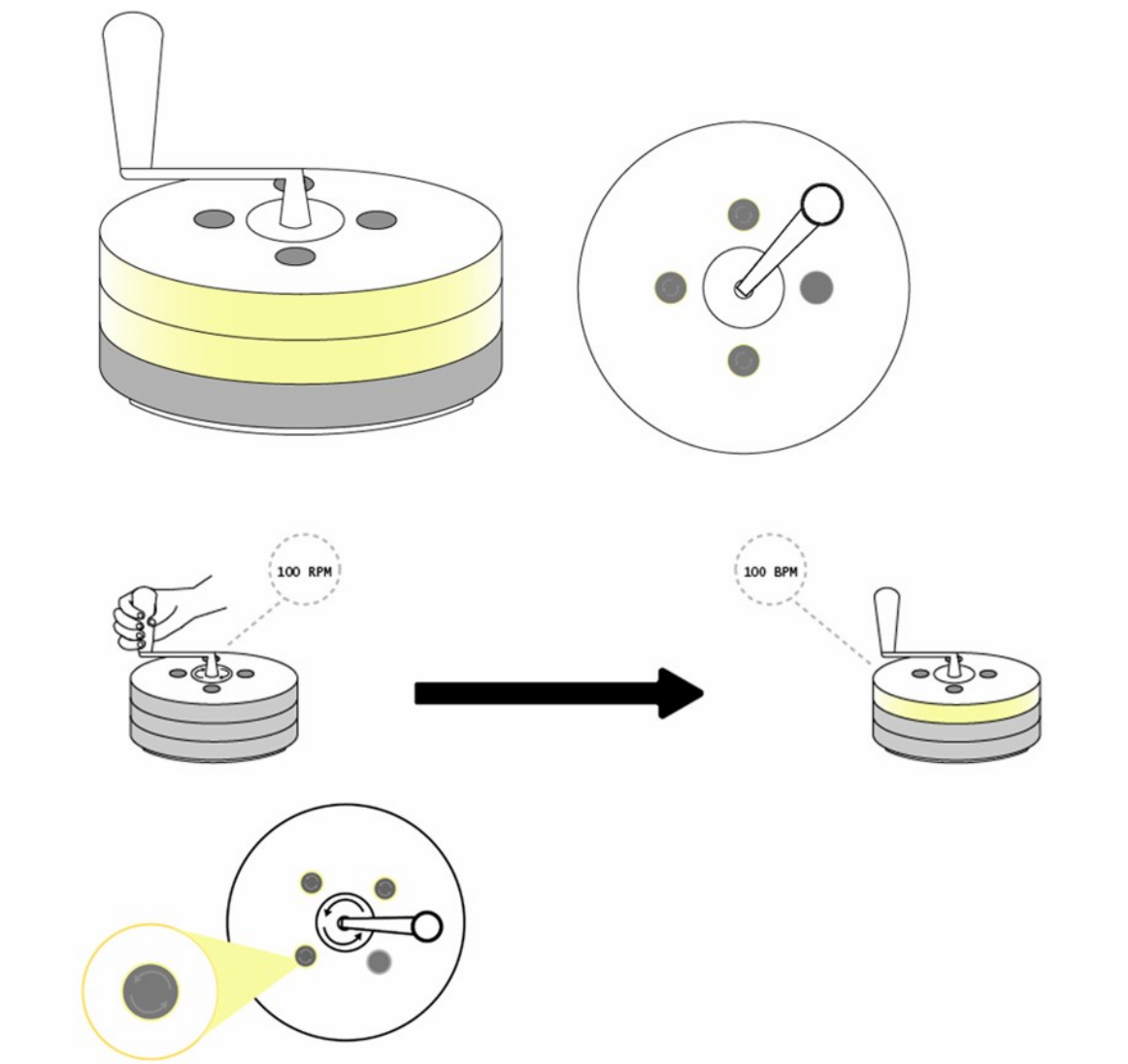
With the Metronome Queue Player design concept, users would toggle a pendulum (see bottom image) either to the left (for a slower tempo) or right (for a faster tempo) to establish a tempo for song selection. Once selected, this new tempo would enter the queue and songs from that tempo would begin to play after the currently playing song. The pendulum would then oscillate at this tempo until a new tempo was selected. The color of the Queue Player would also change—ranging from blue (slowest tempo) to red (fastest tempo)—depending on the current tempo (see top image).

B Heartbeat Queue Player



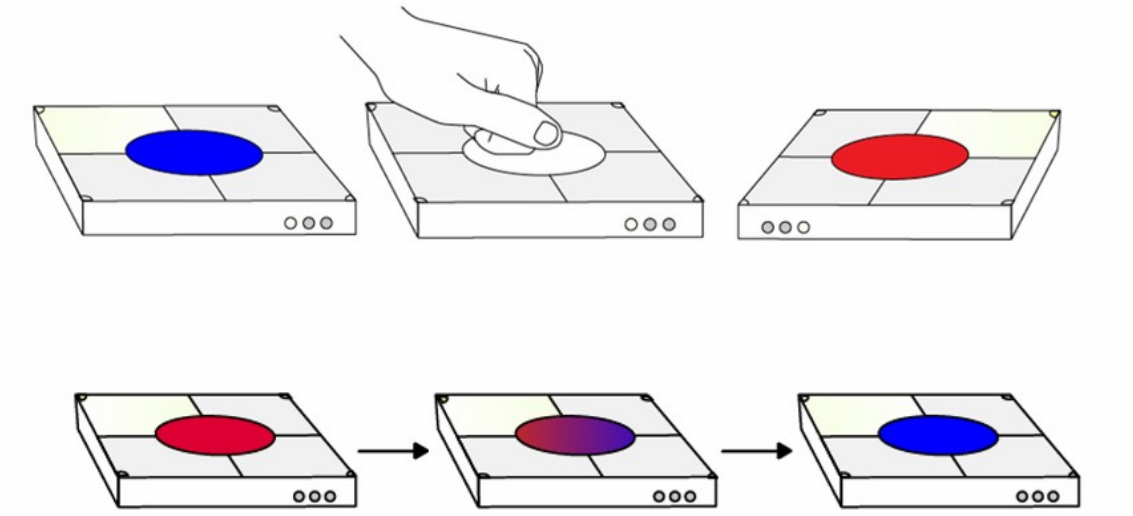
With the Heartbeat Queue Player design concept, users would place their finger on a pulse reader to record a new tempo for song selection (see bottom image). A ring light surrounding the reader would pulsate to reflect the user's heartbeat, and the tempo of the pulse would be added to the queue. Songs at this tempo would be played after the completion of the currently playing song. Colored lights at the top of the Queue Player, corresponding to each user, would also subtly pulse to preview new tempos input by users in the queue.

C Revolving Queue Player



With the Revolving Queue Player design concept, users would rotate a handle at an arbitrary RPM (rotations per minute) to establish a new tempo for song selection. This RPM value would be converted to a corresponding BPM value and added to the queue (see middle image). Songs at this tempo would be played after the completion of the currently playing song. Small disks on the top of the Queue Player (see bottom image), each corresponding to a specific user, would also rotate to indicate which users have listened to the currently playing song in the past.

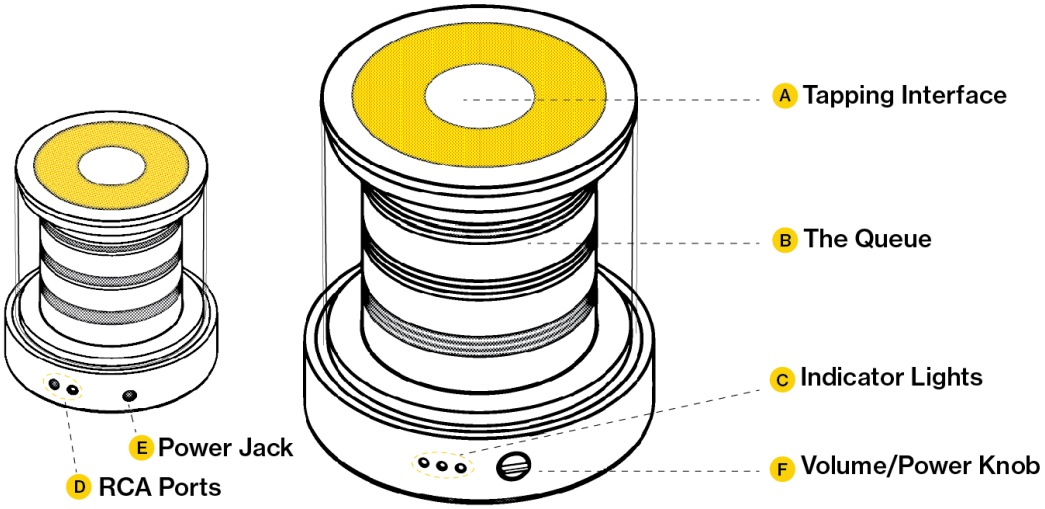
D Tap Tempo Queue Player



With the Tap Tempo Queue Player design concept, users would tap a steady tempo on the center of their Queue Player to establish a new tempo for song selection (see top image). This song would then be added to the queue, and played after the currently playing song. Songs would continue playing at this tempo until another user taps a new one. However, if left untouched, the Queue Player would noticeably decrease the tempo until a user responds with a new tempo (see bottom image). Squares at the top of the Queue Player, corresponding to each user, would light up to indicate when they tapped a new tempo to be added to the queue. The color of the tapping interface would also change—ranging from blue (slowest tempo) to red (fastest tempo)—depending on the current tempo (see bottom image).

E Queue Player Zine

F Queue Player Diagram



F.1 A: The Tapping Interface.

The Tapping Interface has two functions:

- Tapping a steady tempo on the surface will allow you to select a new tempo to be added to the Queue.
- The interface will light up the color of the user who tapped the current tempo and will pulse at this tempo. Subsequent songs will match this tempo until another tempo is added.

F.2 B: The Queue.

The Queue shows all of the songs that are currently lined up to be played and is made of four sections that are lit up by LEDs. Four songs will be displayed at a time, with each song being represented by a certain color (orange, yellow, green, or violet) and each color representing a certain user.

The color of each song shows which user 'owns' a particular song, and a gradient of colors shows the multiple users who have listened to a song in the past.

The top-most section of the Queue represents the currently playing song, while the sections below represent subsequent songs. At full brightness, songs in the Queue will be the same tempo as the currently playing song. Once a section of the is dimmed, this represents a newly added tempo to the Queue and subsequent songs will match this tempo until another tempo is added.

F.3 C: Indicator Lights.

The indicator lights show which users are currently listening to their Queue Players. Depending on which users are listening, the light that corresponds to the color of a user's Queue Player will turn off and on to indicate whether they are co-listening.

F.4 F: Volume/Power Knob.

The volume and power knob controls the volume at which music is played when the knob is turned towards the right, and the power is turned off when the knob is turned all the way to the left. Once the power is turned back on, the Queue Player will continue playing music and sync to the current timestamp of all active users.