Queue Player: Co-listening to Promote Social Connection and Reflection

by

Samann Pinder

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Degree:	**Master of Science**
Title:	**Queue Player: Co-listening to Promote Social Connection and Reflection**
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	William Odom Supervisor Associate Professor, Interactive Arts and Technology
	Carman Neustaedter Committee Member Professor, Interactive Arts and Technology
	David Chatting Examiner Innovation Fellow Open Lab, Newcastle University

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Abstract

Music streaming services like Spotify are used to collect and store users' digital music over time and often mediate in-person and asynchronous remote interactions. However, there is inadequate support for distributed synchronous co-listening, and for distance separated social groups to persistently explore their growing listening histories. To investigate these tensions, I introduce *Queue Players*, four tangible networked music players that leverage the combined listening histories of close friends living apart. Queue Players enable synchronous co-listening, fostering social interactions over distance and promoting reminiscence of past listening experiences. I discuss my two-phase research project: First, engaging in a Research through Design process that informed the creation of finalized Queue Player research products. Second, a 6-week field study in which Queue Players were deployed to the households of four close friends living in Metro Vancouver. I present findings from this study and offer insights and implications for future HCI research and practice.

Keywords: Digital Music; Co-listening; Reflection; Social Connection; Slow Technology; Research through Design

This thesis is dedicated to everyone who helped foster my love for music and curiosity for design.

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List of Acronyms

RtD	Research through Design
HCI	Human Computer Interaction
BPM	Beats Per Minute

Glossary

Moments	Brief events in which something occurs, which can potentially influence later events
Encounters	Instances where separate components come together or gather
Transitions	Instances when tasks are taken over, materials are changed, or prototypes or samples are left behind
Pauses	Short or long events that indicate moments of waiting, doing nothing, staying still, and standing back
Other-time	The temporal lifeworld of non-researches in the project that may influence or prompt events

Chapter 1.

Introduction

As music consumption has evolved over time, it has often played a role in people's self-expression, identity, and social interactions [11, 12, 25, 29]. The contemporary emergence of music streaming platforms has also enabled listeners to easily engage with their music as they go about their daily lives, with people listening to an average of over 20 hours of music per week[1]. As people's music collections accumulate over years of streaming, the ability to unpack songs from the past has become a paramount topic of interest in the HCI community, and in the music streaming industry.

Music streaming services like Spotify primarily recommend new music to users and allow them to archive their music listening histories. Spotify, in particular, has also begun to explore listening history revisitation to a very limited extent through features like Wrapped[2], an end-of-year report of one's listening habits over the past year, as well as AI DJ[3], which occasionally resurfaces several songs from a few years back in one's past. Their Repeat Rewind[4] feature also enables users to revisit songs from a more recent past (approximate one month prior) and reminisce on songs that were frequently played. However, all of these features lack the ability to easily and persistently go deep into one's past and reflect on previous moments in one's life. Accessibility to one's listening history can enable users of these platforms to form new connections to songs as they revisit them either through listening alone or through listening with others. However, such history does not exist in a form that is readily accessible, easy to obtain, or intelligible and interactive for all end users. Moreover, the dematerialization of music collections and listening histories makes it difficult for users to contextualize and

[1] https://www.billboard.com/business/business-news/ifpi-2023-music-consumer-study-listening-habits- piracy-ai-1235552024/

[2] https://time.com/6340656/spotify-wrapped-guide-2023/

[3] https://newsroom.spotify.com/2023-02-22/spotify-debuts-a-new-ai-dj-right-in-your-pocket/

[4] https://20230524t095215-dot-pr-newsroom-wp.uc.r.appspot.com/2019-09-24/introducing-two-new-personalized-playlists-on-repeat-and-repeat-rewind/

meaningfully interact with their listening data beyond the means music streaming services provide.

This issue becomes compounded when listeners wish to share and reflect on their listening histories with others, especially when listening with close friends and family members. Currently, music sharing technologies largely cater to *asynchronous listening*, which occurs when music is shared but not listened to in the same place or at the time of sharing [9]. While asynchronous music sharing has been shown to cultivate relationships and engage listeners in social connection [22, 33, 56], it does not provide the same richness and level of intimacy that can be felt through listening to music simultaneously while in a shared space [28]. Once physical distance becomes a factor in music sharing, it is often a challenge to sustain a sense of interpersonal connection without some form of tangible mediation.

Nascent HCI research [35, 38, 69] has begun to explore *synchronous*, evenly distributed music listening , i.e. *co-listening* [64], and begun to illustrate its potential to encourage social bonding and cohesion. Lottridge et al. also emphasize that synchronicity when listening to music over distance can "help to support reflection, feeling of presence and shared-experience"[43]. However, co-listening over distance is still emerging in both the HCI community, and with industrial products. Spotify's 2023 release of *Jam*[5] has introduced co-listening over distance, allowing users to listen to and equally control the music shared with loved ones. This feature serves as a significant step towards achieving a truly shared listening experience across significant distances. Yet, it still presents limitations that can be seen as drawbacks to some users. One of these drawbacks is the ephemeral quality of such listening sessions, as once a *Jam* session is over, there is no way for listeners to pick up where they left off, revisit music that was played during the session, or continue to tend to a shared listening experience over time. Another disadvantage of *Jam* sessions is that, while song suggestions are provided, the feature heavily relies on users' addition of songs to share with others. With each user likely having such a vast library of music, they may become burdened by the choice of what to play [39, 41] when having to continuously choose songs. Furthermore, *Jam* sessions do not offer rich interaction modalities to support social exploration and sharing, nor do they offer diverse expressions of social presence. Finally, while *Jam*

[5] https://support.spotify.com/ca-en/article/jam/

facilitates connection over distance by simulating a collocated music listening experience, users may also experience a sense of loss for the lack of something tangible to anchor themselves to the experience and the ones sharing in it.

The emerging development of distributed co-listening creates new opportunities in the HCI community to investigate how groups of users can efficiently re-experience and navigate through their extensive music libraries when combined. As individuals continually listen to music on their own, they accumulate diverse collections of music that can be easily explored through using conventional filtering methods such as by artist, genre, or release date. However, temporal modalities (i.e., "the application of different forms of time" [49]) like timestamps have also been shown to be highly valuable modality for navigating personal data histories like music-listening history archives, photos, location data, and hiking data (e.g., [6, 8, 47, 50, 52, 54, 73]), while also offering alternative perspectives on one's life and data that may not materialize through conventional filtering methods like those noted above. Temporal modalities have also demonstrated a capacity for prompting reflective, ongoing, and open-ended experiences for users. Tempo is another example of temporal modality that is intrinsically tied to music and our nature as human beings, as we all have our own internal rhythms (e.g., circadian rhythms, heartbeat) and external rhythms (e.g., routines, seasonal traditions) that are structured around pacing and time. This presents a rich and unifying framework for people to relate to and navigate their music listening histories through, both individually and socially, yet it has been unexplored and unutilized in currently existing music-listening technologies. Navigating music via a common metadata shared among co-listeners' songs (e.g., tempo) offers promise to facilitate open-ended experiences such as curiosity, reflection, interpretation, or even contemplating interconnections among songs that multiple co-listeners may have previously listened to. In parallel, previous research [27, 47, 51, 55] has shown that mobilizing different forms of time or temporal expression can open up opportunities for reflection by supporting alternative pathways of exploring one's music, and invoke more opportunities for contemplation and interpretation of songs. This suggests that temporal modalities can be utilized for physical input interactions in music-listening technologies as well, so that listeners can form new perspectives on their music and how they approach listening in everyday life.

The use of temporal modalities aligns well with the principles of slow technology, which is a design approach 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. Slow technology's emphasis on pacing allows users to gradually discover new layers of meaning and reflection in their interactions with technologies. However, music-sharing technologies that incorporate temporal modalities to facilitate such reflective and meaningful experiences—particularly in the context of social listening and synchronous distributed co-listening—remain non-existent. My research specifically focuses on the intersection among co-listening, temporality, and tangibility and explores how the design qualities of a physically interactive music player can bring these concepts together. My aim is to investigate how the physical embodiment of people's personal music listening histories and data when combined with others', can facilitate co-listening experiences over distance which are similar to those while collocated. I also want to examine how the combination of people's personal histories for mutual exploration can potentially lead to opportunities for interpersonal connections, group reflections, and social connection among listeners. Finally, in relation to slow technology, I want to explore how this design philosophy might be mobilized to foreground the value of temporality when nurturing richer interaction and more reflections with longer-term music listening in ways that can scale and evolve over time.

My thesis addresses three research questions and their sub-questions:

1. How could a novel tangible music player enable long-term synchronous co-listening for physically separated individuals with close social ties?
    a. In what ways might such a system encourage experiences of social bonding, social awareness, intimacy, and reflection?
2. How might a slow technology lens enable ongoing experiences of co-listening to music proportionate to a lifetime of a social group's shared history of digital music?
    a. How might the use of a temporal metadata, like tempo (i.e., Beats Per Minute), play a role in facilitating open-ended experiences and a range of emotional qualities among co-listeners?

3. How do people perceive their music listening history when it is transformed from an immaterial and largely inaccessible digital archive into a physical form present in their everyday life?

    a. How does this play out on an individual level? How does it map to their individual life history? What stories, experiences, and associations are perceived and re-experienced in it?

    b. How does this play out on a social level? How does it shape and mediate social connections among the friend group (e.g., on a friend-to-friend level and on a collective level)?

To investigate these questions and ground my own thinking in this space, I designed *Queue Player*, a novel tangible music player that mobilizes tempo metadata (i.e., beats per minute) to support open-ended experiences amongst a group of co-listeners and their collective music-listening histories. Through adopting a Research through Design (RtD) process when creating Queue Player, and through deploying a small batch of four units in a field study over 6 weeks, the goal of my research was to explore how a group of friends might engage in social connection through co-listening via tempo as an interaction modality. Queue Player materializes the music listening histories of four friends, allowing them to traverse an archive of their combined histories in the form of an ever-changing, embodied queue of songs. The Queue Players act as a network, operating by accessing users' songs from the shared song archive according to a tempo, i.e., a tap tempo, which is selected by the user. Users can tap varied tempos to "choose" which songs emerge from the archive and populate the queue according to that specific tempo. To allow each user to feel the presence of the other users over distance, the Queue Players also indicate which users are actively co-listening via small LEDs that turn off and on whenever a user actively joins or leaves a listening session.

In this thesis, I describe and unpack my Research Through Design (RtD) approach [20, 76] which ultimately led to the creation of a small batch of four Queue Player artifacts. Then, I detail a field study of the interconnected Queue Player network with four participants over six weeks that investigated how these design artifacts could be used to foster feelings of togetherness and allow for personal and social reflection.

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 opened up discussions around navigating combined histories and data over long periods of time.

This thesis makes two contributions to the HCI community. First, it introduces a set of novel music players, *Queue Players*, in which tempo is used as a temporal modality for interaction. This makes listening history metadata materially presented to its users so that they can interact with it directly, and also provides insights into how tangible music-sharing devices can support open-ended co-listening experiences. Second, it offers a design research case that further expands strategies for how slow technology can fit into everyday objects in people's lives, so that they can intentionally interact and evolve with these objects over long periods of time.

1.1. Overview of Chapters

Here, I provide an overview of the following chapters in my thesis:

In Chapter 2, I present a literature review of related works. Related work spans the categories of digital music listening practices and co-listening, personal data, slow technology, slowness and temporality, and designing for subtle social presence.

Chapter 3 outlines the methodology for my research project and presents Queue Player as a novel Research through Design case. I highlight the two-phase process of the project: the formative phase and the finalization phase. The formative phase includes positionality and framing, initial inspirations, design concept proposals, and the Research through Design process. The finalization phase showcases the final version of the Queue Player research products and depicts the process of preparing for a field study deployment of the Queue Players.

Chapter 4 is an account of the findings from the Queue Player field study. This includes how Queue Player supported synchronous distributed co-listening experiences among four friends living apart, as well as various reflections they shared throughout the study.

In Chapter 5, I discuss implications of the findings, and identify several considerations for the design of future systems for synchronous distributed co-listening and other co-experiences surrounding shared data.

In Chapter 6, I share limitations that occurred throughout my research project, and considerations for future work.

In Chapter 7, I conclude my thesis by revisiting the research questions and summarizing findings for each. I also state my core research contributions and identity areas for future research and design practice.

Chapter 2.

Background and Related Work

2.1. Digital Music Listening Practices: Personal and Social

With the evolution of music listening devices, people's relationships to music and music listening practices have continually shifted. The late 1800s saw the invention of the Phonograph and Gramophone, while the 1900's introduced listeners to vinyl records, portable stereos, cassette tapes, boomboxes, the Walkman, CDs, and eventually the MP3 player [79]. Digital music became prevalent during the early 2000s and made music collections more portable and easily accessible once the iPod was introduced [80]. As digital music listening on iPods eventually evolved into digital music streaming via services like Apple music and Spotify on smartphones, smart watches, and computers, music listening with others through these services has also become a topic of interest in both industry and the HCI community.

Through novel applications and studies surrounding digital music streaming, prior research (e.g., [9, 23, 33, 59, 69]) indicates how it has provided an avenue for friends and family members to connect, by allowing them to easily extract songs from their music libraries and share them amongst each other. Researchers have also emphasized the role music sharing plays in encouraging social cohesion [23, 38, 63], though many studies that explore this role have exclusively supported asynchronous music sharing. As a result, the potential for simultaneous music sharing, especially across geographical distances, has been relatively unexplored.

Music streaming platforms like Spotify have recently begun to explore different avenues for social engagement through features that enable both synchronous and asynchronous music sharing. With over 100 million songs and 626 million users worldwide, Spotify is currently the world's most popular music streaming service[81]. Spotify's prevalence makes it an ideal platform for developing technologies for social connection through co-listening. Spotify's social streaming features like *Blend*[6],

[6] https://support.spotify.com/ca-en/article/social-recommendations-in-playlists/

Collaborative Playlists[7], and *Jam* all allow social groups to add, remove, and reorder songs so that they can listen together, though with different degrees of control over the music shared and situations of where and when listening can take place. While the freedom for listeners to fully curate and control music-listening sessions has the potential to promote feelings of connectedness with those they share music with, there are limitations that present themselves with both asynchronous and synchronous listening in their current state.

One significant challenge that extends to both asynchronous and synchronous music sharing scenarios lies in the complexity of song selection and playlist curation. Krause et al. suggest that the ability to freely choose music often enhances music-listening experiences [37], though the option to add and remove songs from extensive collections of music, especially when several listeners' music collections are involved, has been shown to diminish chances to experience anticipation and may overwhelm and even burden listeners [39, 41]. Similarly, intentionally skipping songs while listening to music with others may evoke feelings of exclusion if one's songs are repeatedly removed or ignored. Continuously choosing music to maintain listening sessions may also become tedious to users [68], which may discourage simultaneous listening over time.

HCI research that explores synchronous music sharing unveils further complexities for both those who are collocated and sharing remotely. Bassoli et al. present *tunA*, an application that runs on Pocket PC PDAs and 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]. While *tunA* allows users to form social bonds through co-listening and emphasizes the value in synchronized listening, it also allows users to voluntarily connect with others if they find their music appealing. This approach is valuable in developing interpersonal bonds within a social group, but can limit bonding amongst the entire group in a collective co-listening experience. Lenz et al.'s *Mo* [38] is a proposed personal music device that supports co-listening amongst people who are collocated. *Mo* allows co-listeners to play their music during social gatherings and to select and merge songs from nearby *Mo's* into a combined playlist, fostering feelings of intimacy and serendipity. However, *Mo's* features for selective listening, and allowing

[7] https://support.spotify.com/ca-en/article/collaborative-playlists/

users to “pre-listen” to songs before playback, may restrict the amount of equal control and sense of connection amongst listeners. Conversely, Tibau et al.’s *FamilySong* [69] facilitates co-listening across both geographical distance and generations, as it connects family members through a shared synchronous listening experience. While *FamilySong* also necessitates additional devices such as a cell phone, tablet, or computer for users to interface with Spotify for song selection. User-driven song selection may prioritize crowd-pleasing over personal preference, potentially diluting the intimacy of the co-listening experience. These social streaming limitations in *tunA, Mo* and *FamilySong* point to the critical dilemma between personal music streaming and what Hagen and Lüders describe as “valued social object” once one’s music becomes a shared commodity [23]. An individual’s music listening practices often reflect elements of their personal lives and daily routines, and make freely sharing with others an intimate and vulnerable experience. At the same time, openly sharing and entrusting parts of one’s music-listening history may strengthen the social bonds and interactions between them and their loved ones, and potentially expose them all to broader musical tastes and diverse interpretations of their music [23, 71].

The research I present in my thesis aims to address these research gaps previous works by investigating how a novel music player like Queue Player can be designed to support equal control of music while co-listening over distance. It also considers the implications of choice in co-listening sessions, and how it can shape how and when people interact with Queue Player.

2.2. Personal Data, and Data within a Social Context

There has been a continued interest in the HCI community with how people’s personal data can be used as a resource for encouraging self-reflection and recollection when users interact with technologies. This has been investigated through research products that allow for resurfacing media like photos [6, 8, 50], location metadata [73], and music listening histories [51, 52, 55]. 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 social interactions on their music tastes [3, 15, 23, 42, 74]. Graham et al. consider the implications of collective reflection once data is shared with others in social contexts [22]. One key consideration is that a 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. 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 [19]. This gives 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 varying interpretations of songs. Co-listening may encourage listeners to give more personal context their music while others engage with it, encourage a better understanding of oneself, and even inspire more meaningful and intentional music listening in personal music listening practices [74].

Little work has explored the design of new systems that make use of people's vast listening history data as a resource for co-listening, social connection, and reflection. More broadly, design researchers have argued there is a need to design interactions with personal data that expand beyond "an exclusive interest in performance, efficiency, and rational [self] analysis" ([16], page 48). Yet, examples of new design artifacts that demonstrate how such rich engagements with personal and social data can be supported remain relatively sparse.

My research examines the potential music listening histories have for reflecting on oneself in personal and social music-listening contexts. I discuss how openly sharing music while co-listening may also provide opportunities to strengthen social bonds and interpersonal trust through open dialogue co-listeners may have while listening across distance with loved ones.

2.3. Slow Technology Principles in Sustained Interactions

Hallnäs and Redström describe slow technologies as those that "[supply] time for doing new things" [24]. This is done by allowing time for people to understand and reflect on what a technology affords them. The *Long Living Chair* [60] is a rocking chair that

allows people to view how it has been used over the course of 96 years. However, it subtly and slowly displays each interaction so that users can reflect on their time sitting in the chair over time, instead of focusing on each individual use. The minimal display of how much the chair has been used also gives people the time to engage with the chair more intentionally, as frequent interaction is not demanded from the user while 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 [14]. Like the *Long Living Chair*, *Slow Fading* emphasizes unobtrusiveness, builds anticipation for viewing how the fabric has faded through time, and also fades into the background of the user's home and attention. Both of these 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 also suggest the potential of how slow technology can be used 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, and form deeper connections and understandings of shared music as it is played over time. In addition to this, these cases demonstrate how unobtrusive domestic slow technologies can build anticipation by dynamically collecting and presenting data in a consistent, unchanging location over time. Incorporating these qualities into a tangible 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.

HCI research cases such as *PhotoBox* [48] and *muRedder* [34] also build on the concept of intentional interactions, while demonstrating how the combination of scarcity and slowness can lead to more reflective experiences while using technologies. 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. This further reinforces the potential of slow technology in co-listening contexts, as implementing slowness into the consumption of a combined

archive of a social group's music can cultivate more intentional listening and stronger connections to music as it plays.

My research investigates how a slow technology lens can be used to sustain interactions with a tangible music player (*Queue Player*) in a domestic setting over long periods of time between those in an established social group. I also discuss how incorporating different slow technology qualities can evoke various emotional qualities when co-listening on both an individual level and social level.

2.4. Designing for Slowness and Temporality

Several research products have explored temporality in terms of pacing, where users only receive outputs from a device at certain times or with certain temporal modalities [e.g., [6, 8, 27, 47, 48, 52]]. As people continually stream music in their personal lives, their archives grow at a rate that makes it difficult for them to manage and navigate their music over time [40–42] without mediating when and how songs can be revisited. Odom et al. present two music-listening devices, *Olo Radio* [47, 55] and *Olly* [51, 52] that attend to this problem by slowing down the rate at which users' past songs are resurfaced and listened to. With *Olo radio*, users are invited to navigate their music through temporal modalities such as the time of day, month, and year that a song was listened to. In this way, users have direct control over which segments of their listening histories they navigate, and can consciously traverse the timeline of songs they have listened to in the past. With *Olly*, songs from a listener's past are resurfaced at random time intervals, and are pulled from different points in time within the listener's music archive. Here, users' music histories are more passively explored as they have no control over which part of their archive a song is coming from. *Olly* also offers songs for a brief period before switching to a new one if left untouched, and this ephemeral quality of listening further prompts users to reflect on when and why certain songs should be played. In both research products, the emphasis on slowness [47, 52, 55] and users' pasts prompt users to deeply reflect on the implications of their music listening practices, and to approach music with curiosity, openness, and mindfulness.

The research products mentioned above demonstrate pacing in how media is delivered to users. However, *tempo*, as a specific form of input to explore one's history with any kind of media, remains limited in HCI research. This is an especially significant

research gap in digital music listening practices, considering how readily accessible tempo, i.e., beats per minute (BPM), metadata is. Kosonen and Eronen leverage tempo metadata by allowing users to playfully browse their music libraries by maintaining the rhythm of songs between their transitions [36]. Studies like [4] and [10] also utilize tempo as an input modality, by allowing users to browse songs on their mobile device through tap tempo. In all of these studies, tempo demonstrates great promise as an input interaction for exploring ones music history due to its unobtrusiveness, and its ability to be easily replicated by users through tap tempo. Tempo metadata has the potential to present new insights into when people listen to certain songs, and how music can better fit into their existing routines. 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 [62]. Furthermore, integrating tempo into interactions during synchronous co-listening may unveil new perspectives on how people can actively engage with their music. However, it may also reveal tensions in collective digital music navigation through tempo, when considering people’s diverse interpretations of tempo in the rhythms of everyday life.

Tempo also plays a considerable role in synchronous co-listening, 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 [66, 67]. 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.

In this thesis, I discuss how slowness can be used to encourage deeper reflections when individuals listen to and interact with their music in a social context. I also examine how navigating music archives with a temporal modality like tempo can map to the rhythms in people’s everyday life experiences, and how this can support rich reflections on how music surrounds daily routines. Furthermore, I explore how embodied interactions while co-listening (e.g., dancing or singing simultaneously) 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 more intangible. However, many studies have highlighted the important role tangibility and tangible user interfaces (TUIs) play in facilitating peripheral awareness, intimacy, and social connectedness between loved ones. Gaver and Strong [65] describe sociality as a delicate aspect of everyday life, where togetherness is often conveyed and perceived through simple and subtle gestures that communicate emotions rather than explicit information. Similarly, Weiser and Brown ([72], page 2) express the need for "Calm Technology", as interfaces and interactions that are unobtrusive often "[engage] both the center and periphery of our attention, and in fact [move] back and forth between the two."

Tangible artifacts allow for feelings of continuous awareness of others' presence and the surrounding environment, without disruption to routines or any concurrent activities. Hassenzahl et al. [26] further highlight the fact that tangible artifacts provide people with a sense of continual peripheral awareness of others without requiring the level of constant attention that strictly digital interfaces do. This suggests that a tangible user interface for music sharing will also allow for friends and family members to remain connected and aware of each other's presence, despite the challenges that come with physical separation.

Erickson et al.'s theory of social translucence [17, 18] also outlines the concepts of visibility, awareness, and accountability within physical distributed social contexts. While the aforementioned works have shown the importance of tangible interfaces in expressing awareness, Erickson et al. explain that people's awareness of others often results in feelings of accountability to others sharing in the experience. With co-listening, as people become attuned to others listening to music in the same moment, they may consider their actions when deciding what music to share and when to share it with others. Similarly, subtle indicators of presence may further encourage accountability, in that co-listeners may feel compelled to respond with music of their own to convey their presence and willingness to participate with other co-listeners.

In this thesis, I discuss how a tangible music player like Queue Player can support feelings of presence, awareness, and togetherness for co-listeners who engage

in synchronous music-listening experiences over distance. I also examine how subtlety 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.

Chapter 3.

Methodology-Queue Player as a RtD Case

Presentation of the Research through Design (RtD) [20, 76] process of creating Queue Player is broken into two distinct phases: the formative phase and the finalization phase. Next, I include details of the formative exploratory phase that ultimately led to the final, resolved form of the Queue Player research product.

3.1. Formative Phase

3.1.1. Positionality

When creating Queue Player, I engaged in an iterative RtD process. Zimmerman et al. describe RtD as "the process of iteratively designing artifacts as a creative way of investigating what a potential future might be." [77]. I also adopted a designer-researcher position, which emphasizes first-hand insights gained through the creation of real things that embody and bring conceptual ideas to life through their actual existence [5, 13, 51, 73]. Odom et al. also 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." [54]. I will later expand on the Queue Player research team and our design process in sections that follow.

With the global COVID-19 pandemic as the backdrop during the design ideation process, I acknowledged the need for more tangible devices to support co-experiences over distance. As an avid music enthusiast, I naturally gravitated towards the idea of using music as a conduit for such experiences. However, the constantly evolving design process for Queue Player eventually led me to draw inspiration from my Bahamian roots. At its core, Queue Player invites users to explore their shared music histories simultaneously via tap tempo**,** which allows them to tap various rhythms on the top of their Queue Player as an input for song selection. This feature, along with Queue

Player's affordances for co-listening perfectly aligned with the essence of the Bahamian Junkanoo festival.

Figure 3.1 Field Photos from the 2022 Boxing Day Junkanoo Festival.

Junkanoo is a bi-annual cultural festival and celebration that takes place in The Bahamas and attracts both locals and tourists, enveloping them in a kaleidoscope of sounds and colors. It has origins in West Africa, and was brought to the Bahamas as a way of celebrating during and after the period of slavery in The Bahamas [70]. I attended the Boxing Day 2022 Junkanoo festival, and personally experienced a sense of togetherness and social connection with not only the family and friends that I went with, but also the crowd and musicians surrounding me. Amidst the constant beat of goat-skin drums, and the mixture of other percussive instruments like tom toms, cowbells, graters, and saws, rhythm and tempo acted as the glue binding us all together. As I watched us all move in synchronicity to the rhythm of Junkanoo music, I saw how the spirit of the festival mirrored the design concepts for Queue Player, in that tempo also encourages

social connection, feelings of togetherness, and synchronization amongst co-listeners. Junkanoo also ultimately inspired the drum-like form for Queue Player, along with the use of vibrant colors in the design.

I acknowledge that my position as the lead design researcher in this project, and as a Black Bahamian, influenced the design concept for this project. While my research collaborators and I took inspiration from Junkanoo for Queue Player's design, we assumed no appropriation of the festival itself, or Bahamian culture. However, this inspiration allowed me to contextualize Queue Player in a way that resonates with my cultural heritage, while also maintaining a relevance to those with different cultural backgrounds.

3.1.2. Design Iterations

My RtD process for Queue Player took place over the course of 2.5 years. The Queue Player concept was initially developed with my supervisor William Odom, and then realized in collaboration with members and collaborators in the Homeware Lab research group. Our research team included me, William Odom, Ayush Misra, Minyoung Yoo, and Henry Lin, with documentation support from Samuel Barnett. Collaboration primarily took place in Metro Vancouver, with support from Misra taking place remotely further into the design process.

Team	Key Role
Samann	Digital Fabrication, Software Development, Hardware Development
Will	Support with Interaction Design & HCI Research
Henry	Digital Fabrication, Hardware Development
Ayush	Software Development
Min	Software Development
Sam	Documentation Photography

Figure 3.2 The Queue Player Research Team and Their Key Roles.

In working with Odom, we documented each phase of the design process as it progressed and annotated key design choices and decisions in light of our research questions and slow technology framing as we moved towards highly robust and finished versions of the Queue Players. In the following sections, I offer an account of the design process; however, it does not aim to report on each and every design decision. This postmortem accounting attends to specific design decisions that were productively shaped by my research questions and framing.

Next, I introduce early design concept proposals that ultimately shaped and led to the final research product version of Queue Player.

3.1.3. Design Concept Proposals

One of the first decisions in my formative phase was to use tempo as both an input interaction, and for song organization and selection. This was due to the fact that tempo is already an available and easily accessibly form of metadata for songs in Spotify's database, and can be used for song selection as opposed to other methods for selection like artist, genre, and release date. Once the use of tempo was established, I ideated on what interactions could offer an intuitive method for users to interact with their music, while also getting a sense of what BPM they were inputting without explicitly choosing it via a graphical user interface.

Next, I describe and present the five key design concept proposals in my RtD journey to create Queue Player.

A. Metronome Queue Player

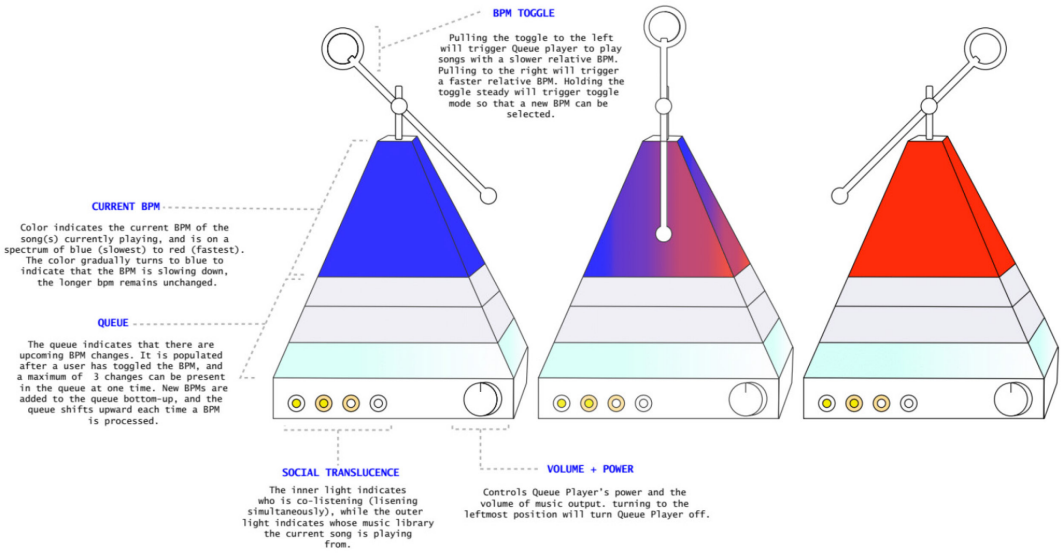


Figure 3.3 Metronome Queue Player Concept and Design Features

Metronomes are commonly used to indicate tempo in music, producing audible clicks at a tempo set by a user [82, 83]**.** For this design iteration of Queue Player, we explored the idea of repurposing metronomes from being used as output devices for tempo to input devices for song selection. With this design, users would pull the toggle of the metronome towards the left to select songs with slower tempos, or towards the right for songs with faster tempos.

One of the advantages of this concept was its familiarity, as users may have been accustomed to the idea of using a metronome to maintain the tempo for songs. However, we ultimately decided to not pursue this design due to its potential end user intelligibility challenges. Without any markers or feedback, it may have been difficult for users to accurately map the tempos they were selecting only through pulling the toggle to the left or right. Incorporating markers, or even tension in the toggle pull would have provided more concrete and intuitive indicators for users to precisely select tempos.

B. Heart-to-Heart Queue Player

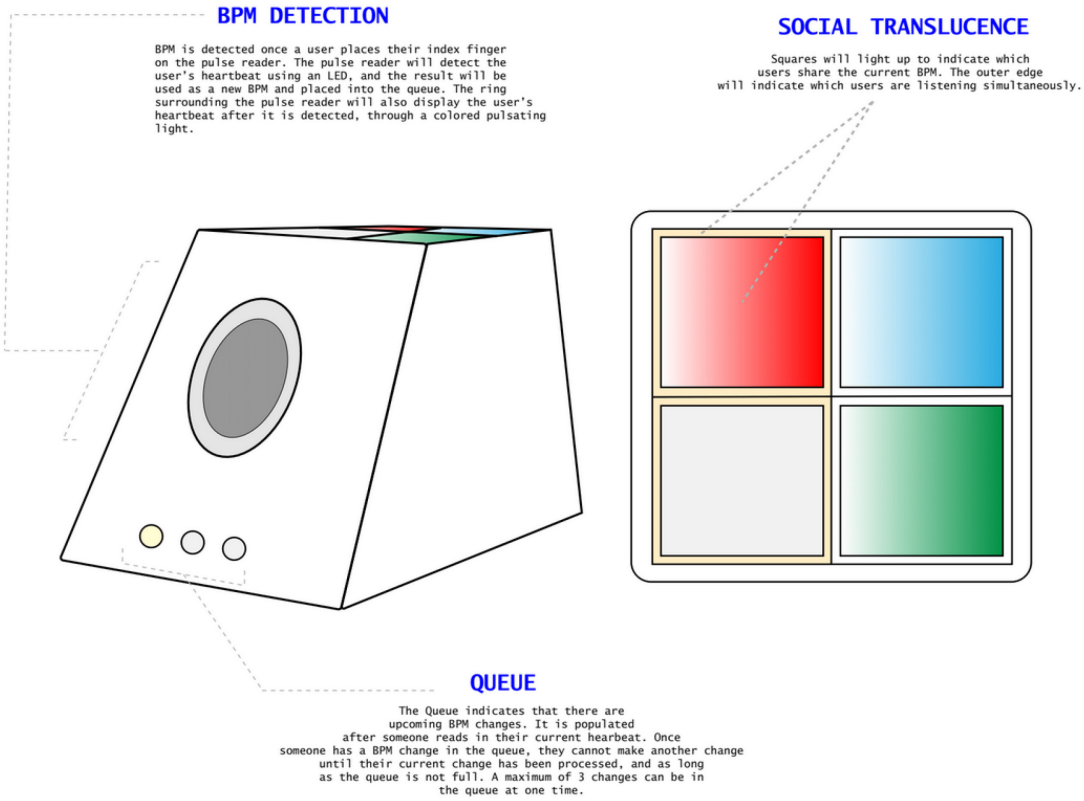


Figure 3.4 Heart-to-Heart Queue Player Concepts and Design Features

Rhythm and tempo naturally course through the human body, with heartbeat often going unnoticed until purposely checked. For this iteration of Queue Player, we envisioned users momentarily monitoring their pulse via a heart rate monitor, and using the reading as an input for song selection.

One advantage of this design would have been its potential to cultivate moments of mindfulness, empowering users to make conscious decisions about when to engage with their Queue Player based on their current heart rate. This would have potentially offered insights into users' activities and emotions at the time of monitoring. However, this design's effectiveness would have been very limited by the possibility of having a narrow range of BPM values available for song selection. For adults, resting heart rates can range from 60-100 BPM, with healthy adults' heart rates ranging from 55-85 BPM

[78, 84]. This limited range would have restricted the variety of songs users could explore, potentially leading to repetitive listening experiences and less engagement with this Queue Player.

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

C. Revolving Queue Player

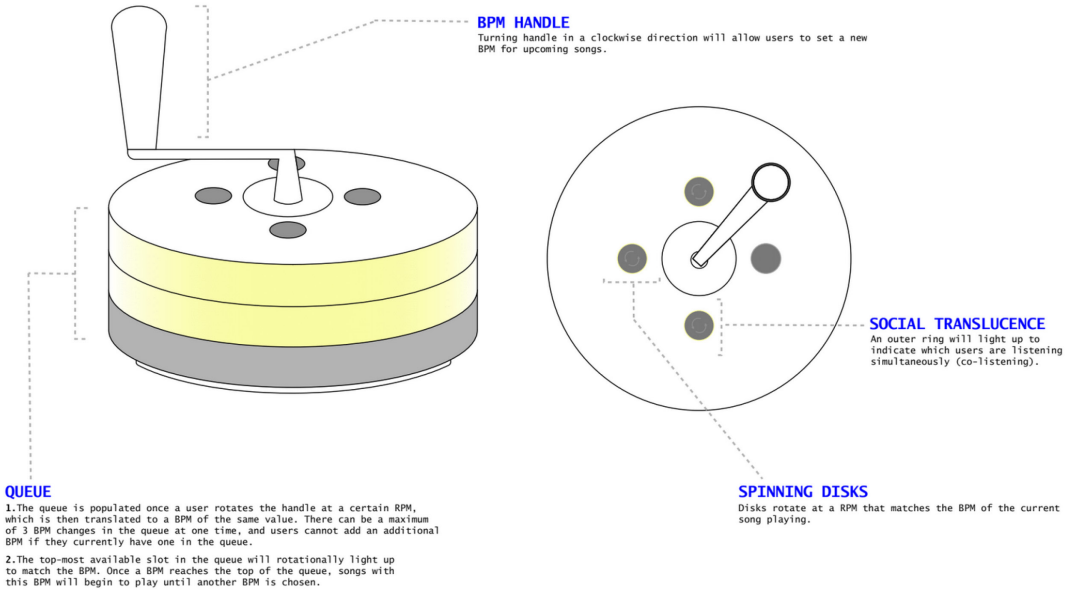


Figure 3.5 Revolving Queue Player Concept and Design Features

Revolutions per minute (RPM) is prevalently seen in physical music-listening media such as CDs and vinyl records, and we conceptualized this as an alternative input for exploring beats per minute. One advantage of this interaction was that users could more intuitively input a BPM that corresponded to the RPM they input by turning the handle on top of the Queue Player (see fig. for design). While this embodied form for song selection would have been promising for intuitively selecting tempos, this design would have potentially been too cumbersome as an input. It would have also required a complex system of rotary encoders for the oscillating discs and handle to rotate as intended.

Although we chose not to proceed with this design iteration, the circular form factor proved useful for visualizing a shifting archive of music (i.e., a queue) in ways that were dynamic, richly minimal, and open to interpretation. We found that the flexibility of this form would allow users to view the current queue of songs from any angle, opening up more potential areas for the placement of Queue Players people's homes. The interaction of turning the handle also moved us closer to the finalized interaction of tapping, as it provided an embodied way for users to understand and replicate tempo for song selection. However, we determined that using RPM as a mapping to BPM was too abstract, and decided to adopt a more direct input interaction of tapping.

D. Tap Tempo Queue Player

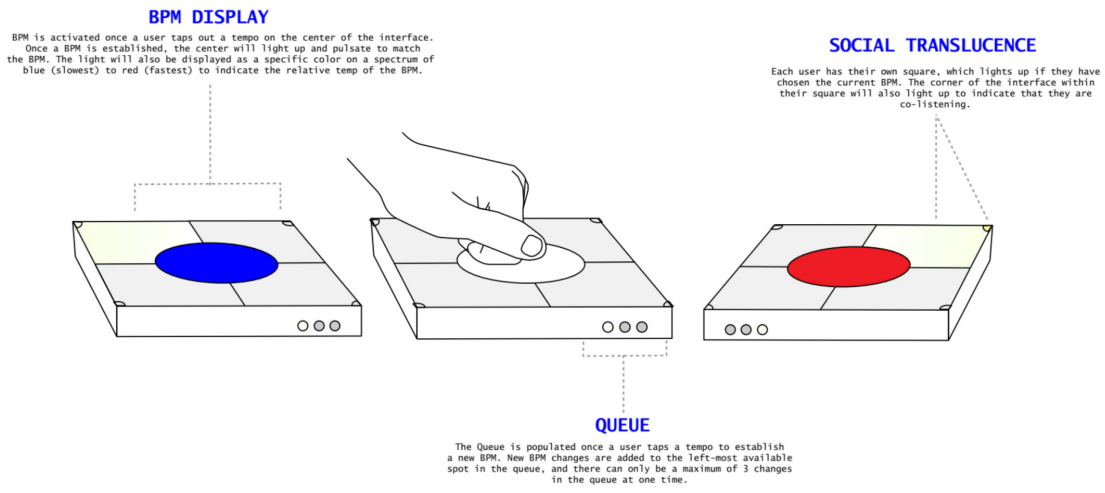


Figure 3.6 Tap Tempo Queue Player and Design Features

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

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. 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. This moved us towards implementing tap tempo for Queue Player's main input interaction.

However, we found that the flat form factor complicated the ability to present an embodied representation of a queue of songs to users. Users would have had to walk up to their Queue Player to see the current state of the queue or its shifting every time they wanted to interact with their it. This approach also clashed with one principle of slow technology, which emphasizes the subtle and seamless integration of a device into users' daily lives. Therefore, we prioritized a circular design for Queue Player that subtly fits into people's homes and makes it easy for users to view and engage with the queue. Through extensive prototyping and iterating on the specificity of the interactions with this design, we eventually arrived at the resolved and final form of Queue Player.

Next, I discuss the design process for this Queue Player, outlining the various stages of development and considerations that informed the decisions amongst the research team.

3.1.4. Queue Player: Design Process and Implementation

The design of Queue Player is highly influenced by concepts distilled from close readings and iterative discussions of theoretical articles on slow technology [24, 45, 46, 49]. In particular, Odom et al. [49] discuss eight key qualities of slow technology that further extend the concepts presented by Hallnäs and Redström [24], and these 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, and temporal granularity and density. Next, I will elaborate on how these qualities were integrated into the design of Queue Player.

Using Slow Technology as a Lens for Designing Queue Player

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 the 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

Figure 3.7 Slow Technology Qualities and Definitions

Queue Player enables a group of four friends to explore a shared archive of their music that has accumulated over the lifetime of their Spotify accounts. The primary interaction for Queue Player 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.

The use of tempo as an input interaction also allows users to draw from their current experiences at the time interaction. For example, if a user taps their Queue Player while exercising, they may be inclined to tap a faster tempo for songs to

accompany their workout. Similarly, if a user is about to sleep, they may input a slower tempo to help them wind down. In this way, tempo, time of day, and people's routines all 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 have no indication of which part of their listening history songs will be pulled from or what emotional quality the songs will have, and tap tempo merely probes users to ruminate on what is to come.

Another feature of Queue Player 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 that tapped the new tempo, and this design decision was informed by several qualities of slow technology. First, the queue lights exemplify *pre-interaction*, as users don'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. This primes users for changes that will occur while co-listening with other users, and also offers opportunities for anticipation and curiosity for what kind of music will be played. Similarly, the queue lights 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 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 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 allows 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. As Queue Player also requires songs to be played to completion, users have no control over how much time their tempo will 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. This gives users time to truly

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.

Amongst four users, there was also a vast amount of music to explore within their shared archive of songs. Though songs are sorted in the archive by lowest to highest tempo, the aspect of the time each user amassed their portion of the archive also introduced a temporal density that had to be attended to. With the rate of music consumption slowed down by restrictions to the queue and the requirement to listen to songs in full, tap tempo also acts as a way to mitigate the frictions that may arise with these qualities in the design. Tap tempo enables *temporal granularity* and 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.

Another feature of Queue Player is the integration of indicator lights to communicate which users are currently co-listening during the current listening session. This 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 [17]. 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.

Crafting a small batch of Queue Player research products

Throughout the making process for Queue Player, a number of design events [57, 58] occurred that influenced the finalized version of the Queue Players and how we conducted a field study deployment. Oogjes and Desjardins describe design events as happenings or "occasions in RtD processes" that contextualize temporalities in design research [57]. I will use some of the vocabulary they propose (**see Glossary**), namely *moments*, *encounters, transitions, pauses, and other time,* to describe different events that occurred during the making of Queue Player.

Developing an approach to working with metadata from multiple listening histories

One of the earliest decisions made while developing Queue Player was how to approach the collection, combination, sorting, and playback of Spotify listening histories from four users. While reviewing other music-listening research products like OLO radio and Olly, we found that those systems work by linking to a user's Last.fm [8]account to dynamically update their song database on a daily basis. Last.fm is an online music database that, once connected to a user's preferred music streaming service, tracks music statistics (through scrobbling) , provides music recommendations, and gives a user access to their entire listening history. While these features were conducive to Queue Player's design, Last.fm wasn't ideal for the final implementation for multiple reasons.

Firstly, due to the tight constraints in our participant requirements—people who were avid Spotify users with accounts dating back to at least three years, who already knew each other and knew me—it was very unlikely to find a group of people who met these requirements and also had Last.fm accounts. Since none of the selected participants had Last.fm accounts, relying on Last.fm would have required them to create accounts and start scrobbling from scratch, potentially leading to an incomplete dataset. Alternatively, Spotify's extended streaming history files provided a comprehensive and precise record of everyone's listening habits and long-term trends and changes in listening behavior, ensuring a richer dataset for them to explore.

Secondly, using Last.fm would have likely increased the computational complexity for the Queue Players, as we would have had to use both the Last.fm API and the Spotify API for song retrieval and playback. Using a static database ensured that all of the data was centralized, making it easier and more efficient to manage, query, and retrieve data for song playback.

Thirdly, Last.fm would have potentially created a feedback loop in participants' listening histories. As they listened to music through Queue Player, the songs that surfaced would have re-entered each participant's personal archive, consequently influencing future interactions with Queue Player. This recursive cycle would have

[8] https://www.last.fm/about

eventually contaminated the archive by diluting the unique instances of each individual's songs in their listening history. This would have made it difficult to discern the original ownership of songs and the contextual significance of each user's listening history. By using each user's extended streaming history from Spotify for the database instead, we were able to preserve the integrity of each participant's listening history and ensure that the data used for Queue Player remained a true reflection of each participant's listening history and habits.

Lastly, the requirement for the Queue Players to play songs synchronously across all devices over distance added another layer of complexity. Synchronous playback requires precise timing to ensure that all users hear the same music simultaneously. This led to the decision to use a local server to manage a static dataset of all users' listening history data and coordinate with the Spotify API, which allowed for more control over synchronization across the Queue Players, reduced latency, and provided a smoother and more reliable listening experience.

Designing minimal interactions for the queue

A focal point in Queue Player's design is the queue, and we iteratively explored how best to display it to users and communicate information about songs as minimally as possible . To achieve this, we first identified the key metadata to convey to users, that would allow them to understand whose music was playing or queued to play, and to reflect on their listening histories. Using a screen as the primary interface would have required too much attention from users. Thus, we decided that light would serve as a subtle yet effective way to represent the queue to users, and also seamlessly integrate a Queue Player into their homes as a lamp. We chose to use Adafruit NeoPixel light strips with warm light to give Queue Player an inviting quality and emit a homely ambiance.

Once the use of light was established, we determined that indicating the ownership of songs, the tempo, and whether a song matched the current tempo or a newly tapped tempo through different colors and brightness levels was ideal way for engaging users without overwhelming them with too much information. We also concluded that displaying only four songs at a time in the queue was most effective in providing users with a glimpse of the current and upcoming songs. This limited number

of songs also allowed all users the opportunity to introduce a new tempo to the queue simultaneously if the occasion ever arose. Given that some tempos had potentially hundreds of songs across all users, displaying only four at a time enabled users to focus and reflect on the immediate songs in the queue rather than being inundated by a vast amount of songs at once.

Next, we iterated on how best to divide light feedback to users across the queue. Taking inspiration from how a queue is created and displayed on Spotify, we designated the first section of the Queue Player queue for the currently playing song, while the second, third, and fourth sections were reserved for upcoming songs. A straightforward decision was to add newly tapped tempos to the next available section of the queue, overriding the upcoming songs and the current tempo once the current song is finished playing. This approach mimicked how adding a new song to a Spotify queue displaces previously queued songs.

We also explored several ideas for communicating a newly tapped tempo in the queue. These ideas included having the lights in sections with new tempos to pulse or rotate at the tempo until reaching the top of the queue. After testing and living with these design iterations for a few days, we determined that both options would be overstimulating to users, especially when multiple new tempos were in the queue simultaneously. This led to the final decision to simply dim the brightness in the section(s) with a new tempo to differentiate between current and new tempos. This approach proved to be the most minimal and unobtrusive way to communicate new tempos in the queue, while also giving the illusion of a new tempo loading. We also chose to display the color of the person who tapped the current tempo with the ring light in the tapping interface.

The final aspect of the queue that we considered was how to indicate a song that had been listened to by multiple users in the past. Initially, we tried having the lights in that specific section of the queue alternate between the colors of the users who shared the song. However, testing revealed that this could potentially lead to users missing some of the colors if they weren't actively watching the section as it changed. The constantly shifting colors could have also been overstimulating if multiple shared songs were in the queue. Ultimately, we decided to use a gradient of the users' colors sharing the song, spanning left to right around the circumference of the queue. This static

gradient could be seen at all times in the queue and better represented a shared touchpoint and ‘blend’ of users’ listening histories, whereas the alternating color approach still isolated users momentarily.

Balancing precision and imprecision with tap tempo

The primary input interaction for Queue Player is using tap tempo to navigate the shared music archive. Queue Player leverages the precise tempo metadata of each unique listening instance of users’ songs to enable a novel interaction design. While we intended users to tap steady and precise tempos on the tapping interface, the tempo at which songs were subsequently played by Queue Player was often imprecise due to the nature of the dataset. Through testing, we found that some tempos tapped had no corresponding songs in the dataset, which prompted us to a method for moving through these voids in the archive. To make the experience as seamless as possible for users, we chose to move to the next closest tempo below the tempo tapped (e.g., if 158 BPM was tapped with no songs available, the algorithm would move to 157 BPM or the next slower closest tempo).

Because the tapping interface also offers no explicit numerical value for the current tempo, we needed to convey the tempo to users while maintaining the minimal nature of the interaction design. Our first idea was to use haptic feedback to communicate the tempo. Although this would have given users a tangible tempo to respond to, there were drawbacks. Firstly, haptic feedback would have required users to approach and touch the tapping interface every time they wanted to know the current tempo, whether they were going to introduce a new tempo or just out of curiosity. Secondly, using haptic feedback would have created interference, as users would feel the vibrations while tapping a new tempo, leading to confusion. This would have potentially hindered users from developing a sensibility to tempo over time. Given that the tapping interface functions as both an input and output, we decided to use light to communicate the current tempo instead. Using an Adafruit NeoPixel ring light, we explored both pulsing and rotating light displays. Ultimately, we chose a subtle pulsing animation as it was more intuitive for users to gauge the current tempo and then tap a new tempo that was either slower or faster than the frequency of the pulsing. The

pulsing would also allow users to see what the current tempo was from anywhere in their living space, without having to approach or actively engage with their Queue Player, opening up the possibility for a rich range of tempos and experiences to emerge. For example, a user being able to see what the current tempo is without having to interact with their Queue Player, could influence the types of activities or tasks they performed around that tempo such as exercising or cleaning with faster tempos, or meditating or reading with slower tempos.

Technical Implementation

A. Hardware

The finalized hardware implementation of Queue Player was split into three parts: the tapping interface, lighting system, and interfacing all hardware components with a Raspberry Pi 3B+.

Tapping Interface

Queue Player's primary input interaction is through the tapping interface, which allows for both tap tempo and displays of the current tempo via a flashing ring light. Selecting the optimal sensor for quick and accurate tap detection was crucial. This automatically eliminated capacitive touch sensors due to their slow response times. We also wanted to maintain the reference to Junkanoo drums, which feature flat contact surfaces. This then excluded the use of a button for this interaction. Finally, we decided on using a vibration sensor to detect the vibration of each tap from a user. Through extensive testing, we ultimately chose a piezoelectric vibration sensor for its effectiveness in detecting taps regardless of speed or frequency. This sensor, equipped with an expansion board, included both analog and digital input pins, and automatically converted the analog vibration signal to a digital signal via a built-in analog-to-digital converter (ADC). This was an essential feature since Raspberry Pi 3B+ boards lack built-in ADCs. Additionally, the sensor included a built-in potentiometer to adjust its sensitivity as needed.

Lighting System

To address the lighting system for Queue Player, we used Adafruit's NeoPixel Digital RGBW LED strips due to their extensive online documentation for Raspberry Pi

integration, and their individual LED control capabilities. The RGBW LEDs provided a broader color range than RGB LEDs and using a 144-LED strip enhanced the quality and resolution to the queue lights. Due to the number of LEDs, they required a 5V power supply to properly operate. This necessitated the use of a 1000 µF capacitor to buffer sudden current changes in the NeoPixel strip.

Hardware Integration

Integrating all components with a Raspberry Pi 3B+ presented significant challenges given the constraints of some components. A significant bottleneck we faced was GPIO pin conflicts between the NeoPixel LEDs and a HiFiBerry DAC+ RTC board. The HiFiBerry is an audio board we used to provide high quality RCA audio output to external speakers for the Queue Players. Through extensive testing and examining the datasheets for these components, we discovered that both the NeoPixels and HiFiBerry both required GPIO pins 10, 12, 18, and 21 [9]and 18-21[10], respectively, with 18 and 21 overlapping. HiFiBerry's requirement for exclusive use of GPIO 18 further complicated matters, as did the NeoPixels' restriction only one strip being created and controlled at a time. To resolve this, we chained all of the NeoPixels (i.e., the queue and ring light LEDs) together and connected them to a single pin (GPIO 12), reserving GPIO 18 exclusively for the HiFiBerry. This setup allowed for individual LED control via software while meeting hardware constraints. This proved to be a significant design event, *an e**ncounter*, in which different hardware components came together and revealed new insights into the finalized hardware implementation.

Additionally, the final implementation included three 3mm colored LEDs for Queue Player's indicator lights, and a B10K potentiometer with a switch for controlling power states. Since the potentiometer output analog signals, we incorporated an ADS1015 ADC chip to convert these signals to digital for the Raspberry Pi.

We integrated all of these components on solderable breadboard PCB, connected this to the Raspberry Pi 3B+. The HiFiBerry board was also mounted on top

[9] https://learn.adafruit.com/neopixels-on-raspberry-pi/raspberry-pi-wiring

[10] https://www.hifiberry.com/docs/hardware/gpio-usage-of-hifiberry-boards/

of the raspberry Pi and connected to Male-to-Female RCA cables for users to connect external speakers to their Queue Player.

We also encountered several design events while completing the hardware implementation. First, The COVID pandemic (an *other-time)*, impacted manufacturing processes and shipping around the entire world. During testing, we had 2 Raspberry Pi's stop functioning (*moments*) , and there were no local or international suppliers that had them in stock. We eventually bought 2 board from a local maker, but the process of finding one, let alone multiple Raspberry Pi's, was extremely challenging. Second, coordinating schedules around traveling, parenting, and new jobs in our research team became a challenge as testing and implementation bounced between our homes and our lab space. These were *pauses* that gradually affected the timeline of completing the project and the field study deployment.

B. Software

The software implementation of Queue Player was developed in two stages. First, we worked on testing the infrastructure with a single Queue Player to ensure that all functions were working as expected. Once one Queue Player was working, we then tested with multiple Queue Players, first while collocated on the same Wi-Fi network, and then remotely over routers designated to each Queue Player. Here, I detail the back-end design for the Queue Player system.

Creating a combined archive of Spotify extended listening histories

Queue Player works by surfacing songs from users' pasts using a static archive of their combined listening histories. To realize this in practice, we had four members of our research team request their extended streaming histories from Spotify for the testing phase. The process of requesting and receiving our data took anywhere from 1 week to a month, which served as another design event, a *pause,* in the design process. We were unable to move any further ahead with the software implementation without the data, and this was also something we faced with participants later on that further impacted the field study timeline.

However, once the data from our research team members was received, we attached user IDs to each dataset before combining the data into one archive. We then filtered this dataset to remove any podcast and video instances, to only include music in the finalized version. We then cross-referenced all songs with the Spotify database to ensure that Spotify Canada had access to them all; any songs that were unavailable were excluded. We also encountered cases where multiple versions of the same song (e.g., single vs. album versions) caused repetition during listening sessions. This address this, we removed duplicate instances of songs in the dataset and prioritized instances that were shared between multiple users, to avoid back-to-back repetition. The data was stripped down to include only the user ID, track name, and Spotify track URI/track ID. This allowed us to scrape additional metadata such as tempo and song duration for sorting the dataset and facilitating song playback via the Spotify API. Finally, the data was organized into tempo 'containers' and sorted from slowest to fastest.

Establishing a server-client connection and configuring song playback

The next step was to create the main server that would liaison between the Queue Players (clients), and also make requests to the Spotify API. The script for this server was written in JavaScript and the app was hosted on the Heroku cloud platform[11]. For client communication, we configured the server to keep track of and notify all Queue Players of which users were active or inactive, 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). We ensured that the server would send all of this information to the Queue Players each time there was a queue update (i.e., when a new tempo was added to the queue, or when transitioning to a new song), to keep all Queue Players up to date and as synchronized as possible. Once the server-client communication was established, we used a WebSocket to maintain an open connection, allowing the Queue Players to receive information in real-time and respond accordingly.

[11] https://www.heroku.com/platform

To enable song playback for Queue Player, we used Spotifyd[12] to configure the Raspberry Pi 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 issues that might have occurred between the server and Spotify API once the Queue Players were deployed to separate households.

Using randomness as a way of navigating the combined archive

While we initially sorted the archive by slowest to fastest tempo, we decided that introducing randomness into the algorithm's design could lead to more open-ended experiences by evoking feelings of serendipity, curiosity, and anticipation for users. This approach would also increase the *temporal granularity* of Queue Player by providing another avenue for visiting more parts of the archive. To achieve this, we examined various audio features available for tracks on Spotify and identified danceability (a measure of how suitable a track is for dancing based on its tempo and rhythm) and valence (the emotional quality of a track) as key factors in shaping the overall mood of a listening session. These features, measured from 0.0 to 1.0, allowed us to categorize tracks within each tempo ‘container’ into four categories: High Danceability-High Valence (HDHV), High Danceability-Low Valence (HDLV), Low Danceability-High Valence (LDHV), and Low Danceability-Low Valence (LDLV). We then employed a machine learning algorithm to re-sort the database around these categories into four distinct clusters, which were used to guide the listening sessions with Queue Player. The process for the machine learning classification was as follows:

[12] https://github.com/Spotifyd/spotifyd

1. The Spotify data columns were filtered, and unnecessary metadata were removed:

```
In [2]: import numpy as np
        import pandas as pd
        from sklearn.cluster import KMeans
        from scipy.stats import zscore
        import matplotlib.pyplot as plt
        import seaborn as sns
        from kneed import KneeLocator

        df = pd.read_json("qp_pd_multiuser_reformatted.json")
        df["cluster_type"] = ""

In [3]: print(df.columns.values)

['user_id' 'track_name' 'track_id' 'tempo' 'danceability' 'energy'
 'liveness' 'valence' 'cluster_number' 'cluster_type']

In [5]: # preview the log data
        df.head()
```

Out[5]:

	user_id	track_name	track_id	tempo	danceability	energy	liveness	valence	cluster_number	cluster_type
0	[1]	Circles	21jGcNKet2qwijlDFuPiPb	120	0.695	0.762	0.0863	0.5530		
1	[1]	Witch House	0RoJGJA3g0Oop7xDfsbTw9	170	0.313	0.932	0.0895	0.3790		
2	[1]	ODD FUTURE	0yy8QwH9OOgeF3CBeUDguR	128	0.694	0.795	0.1140	0.5560		
3	[1]	Bandaid	0aAbiu9MoE1bAJaqKlZeCk	200	0.370	0.994	0.1370	0.0865		
4	[1]	Help	1cf7XYOKM0FW2K2zpyFFGC	121	0.556	0.863	0.1020	0.3540		

Figure 3.8 Filtering columns to focus only on necessary metadata for our implementation

For the purposes of our implementation, only user ID, track ID, tempo, danceability, and valence were necessary.

2. The Z-score was calculated to normalize values in each column:

Z-Score

```
In [8]: df.insert(3, 'Z_Valence', df['valence'].transform(zscore))
        df.insert(3, 'Z_Liveness', df['liveness'].transform(zscore))
        df.insert(3, 'Z_Energy', df['energy'].transform(zscore))
        df.insert(3, 'Z_Danceability', df['danceability'].transform(zscore))

In [9]: df.head()
```

Out[9]:

	user_id	track_name	track_id	Z_Danceability	Z_Energy	Z_Liveness	Z_Valence	tempo	danceability	energy	liveness	valence	cluster
0	[1]	Circles	21jGcNKet2qwijlDFuPiPb	0.681178	0.865909	-0.624366	0.638645	120	0.695	0.762	0.0863	0.5530	
1	[1]	Witch House	0RoJGJA3g0Oop7xDfsbTw9	-1.460881	1.499878	-0.602094	-0.075015	170	0.313	0.932	0.0895	0.3790	
2	[1]	ODD FUTURE	0yy8QwH9OOgeF3CBeUDguR	0.675570	0.988973	-0.431573	0.650949	128	0.694	0.795	0.1140	0.5560	
3	[1]	Bandaid	0aAbiu9MoE1bAJaqKlZeCk	-1.141254	1.731090	-0.271491	-1.274702	200	0.370	0.994	0.1370	0.0865	
4	[1]	Help	1cf7XYOKM0FW2K2zpyFFGC	-0.098262	1.242561	-0.515093	-0.177553	121	0.556	0.863	0.1020	0.3540	

Figure 3.9 Calculating The Z-score to normalize values in each column

3. We plotted the regression line to investigate the relationship between two variables. Statistically, we chose **Danceability** and **Valence** because they have a positive (but moderate, as the slope is between 0.3 and 0.7) correlation (Increased Danceability could lead to increased Valence.)

```
In [13]: from scipy.stats import pearsonr

df_Sample = df.sample(100) # This is the importante line
xdataSample, ydataSample = df_Sample["Z_Danceability"], df_Sample["Z_Valence"]

# Calculate the Pearson correlation coefficient
correlation_coefficient, _ = pearsonr(xdataSample, ydataSample)
print(f'Slope (Correlation Coefficient): {correlation_coefficient}')

sns.regplot(x=xdataSample, y=ydataSample)
plt.show()

# df_zscore.plot(x='track_id', y='Z_Danceability', kind='scatter')
```

```
Slope (Correlation Coefficient): 0.4198422972999427
```

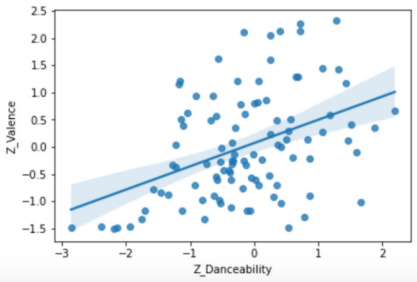
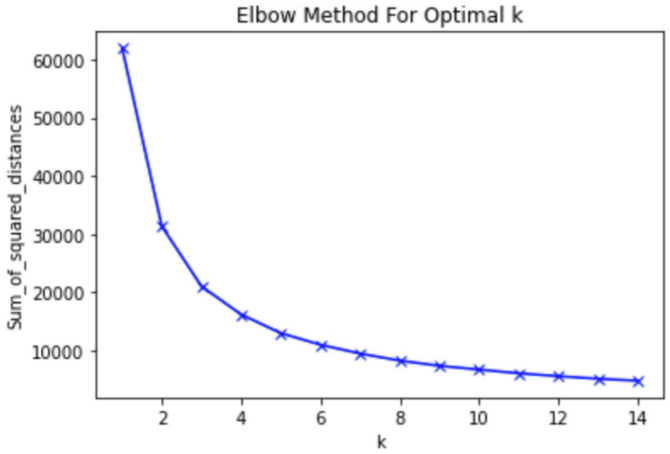


Figure 3.10 Plotting the Regression line to show the relationship between valence and danceability

4. Using the ***k-means algorithm*** and the ***sum of squared-distances method (elbow method)***, we calculated the optimal number of clusters for all the data points (songs) when plotted using Danceability and Valence.

```
In [11]: ### Danceability and Valence (Normalized)

sse4 = {}
Sum_of_squared_distances_4 = []

for k in range(1, 15):
    kmeans = KMeans(n_clusters=k, random_state=1)
    kmeans.fit(df[['Z_Danceability', 'Z_Valence']])
    sse4[k] = kmeans.inertia_
    Sum_of_squared_distances_4.append(kmeans.inertia_)

kn = KneeLocator(x=list(sse4.keys()),
                 y=list(sse4.values()),
                 curve='convex',
                 direction='decreasing')
k = kn.knee

plt.plot(range(1, 15), Sum_of_squared_distances_4, 'bx-')
plt.xlabel('k')
plt.ylabel('Sum_of_squared_distances')
plt.title('Elbow Method For Optimal k')
plt.show()

print("Optimal number of Clusters: ", k)
```

Figure 3.11 Using k-means to calculate the optimal number of song clusters




```
Optimal number of Clusters:  4
```

Figure 3.12 Using the elbow method to calculate the optimal number of song clusters

5. We run k-means on the plotted data points to classify all points by 4 clusters. Four printed coordinates were the center points of each cluster.

Now, run K-means with 4 clusters and assign the clusters for each track

In [22]:
```
### 4 clusters

df_kmeans = pd.DataFrame(df, columns=['Z_Danceability','Z_Valence'])

kmeans = KMeans(n_clusters=4).fit(df_kmeans)
centroids = kmeans.cluster_centers_
print(centroids)

plt.scatter(df_kmeans['Z_Danceability'], df_kmeans['Z_Valence'], c= kmeans.labels_.astype(float), s=50, alpha=0.5)
plt.scatter(centroids[:, 0], centroids[:, 1], c='red', s=50)
plt.show()
```

```
[[-1.25180124 -0.94327816]
 [ 0.94575417  1.25243896]
 [ 0.52091763 -0.59395176]
 [-0.33627317  0.49387818]]
```

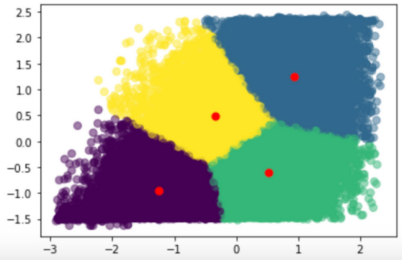


Figure 3.13 Assigning clusters to each song with k-means

6. We labeled each song by the cluster type (HDHV, HDLV, LDHV, LDLV), and ultimately used these clusters for the song selection algorithm.

In [23]:
```
df_copy = df.copy()
vals = kmeans.labels_.tolist()

for i, row in df_copy.iterrows():
    df_copy.at[i, 'cluster_number'] = vals[i]

    # {0: 'LDLV', 1: 'HDHV', 2: 'HDLV', 3: 'LDHV'}
    ctype = ""
    if (vals[i] == 0):
        ctype = "LDLV"
    elif (vals[i] == 1):
        ctype = "HDHV"
    elif (vals[i] == 2):
        ctype = "HDLV"
    else:
        ctype = "LDHV"

    df_copy.at[i, 'cluster_type'] = ctype

df_copy
```

user_id	track_name	track_id	Z_Danceability	Z_Energy	Z_Liveness	Z_Valence	tempo	danceability	energy	liveness	valence	cluster_number	cluster_type
[1]	Circles	21jGcNKet2qwijlDFuPiPb	0.681178	0.865909	-0.624366	0.638645	120	0.6950	0.7620	0.0863	0.5530	1	HDHV
[1]	Witch House	0RoJGJA3g0Oop7xDfsbTw9	-1.460881	1.499878	-0.602094	-0.075015	170	0.3130	0.9320	0.0895	0.3790	0	LDLV
[1]	ODD FUTURE	0yy8QwH9OOgeF3CBeUDguR	0.675570	0.988973	-0.431573	0.650949	128	0.6940	0.7950	0.1140	0.5560	1	HDHV
[1]	Bandaid	0aAbiu9MoE1bAJaqKlZeCk	-1.141254	1.731090	-0.271491	-1.274702	200	0.3700	0.9940	0.1370	0.0865	0	LDLV
[1]	Help	1cf7XYOKM0FW2K2zpyFFGC	-0.098262	1.242561	-0.515093	-0.177553	121	0.5560	0.8630	0.1020	0.3540	3	LDHV
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Figure 3.14 Labeling each song by cluster type to be used in our song selection algorithm

Refining the Queue Player Algorithm

For the finalized version of the algorithm used to organize the queue, we decided to use the danceability and valence clusters to determine the mood of each listening session. If no Queue Players were previously active, the first Queue Player to become active would notify the server, which would then randomly select a tempo and cluster to start music playback. The first song played would also be from this user. We chose to randomize this starting point to allow users to begin each listening session in a different part of the archive each time, providing more diverse experiences and more opportunities to reflect on their past listening habits. Once users tapped a new tempo, we also ensured that the songs played for the new tempo would also be a part of this cluster to avoid any jarring changes in the emotional quality of the music. However, if there were no more available songs in the current cluster, a new cluster would be randomly selected.

Once song playback started, the server would broadcast a starting timestamp to all Queue Players, whether they were active or inactive, ensuring that any device activated later would begin playing the current song at the same time as all active Queue Players. To achieve this on the client side, a local timer on the Raspberry Pi was started as soon as the server's broadcast was received. Through extensive testing, we found that this approach maintained synchronized playback for all Queue Players, with a delay of at most 3-10 seconds.

To account for any latencies in playback, we implemented a 'skipping' function that would force any clients still on the previous song after transitioning to a new one, to reference the timestamp broadcast by the server and catch up with the rest of the clients.

Once a Queue Player became active, the indicator light corresponding to that user would turn on for all other Queue Players, regardless of their active state. This was to ensure that users would know when other users were listening, inviting them to join the listening session and begin co-listening.

To address a tempo 'container' being exhausted of its songs, either through a limited songs available or the tempo remaining unchanged for a long time, we chose to automatically move to the next slowest tempo in the archive. This was to incorporate

ongoingness, and to allow users to continue an uninterrupted exploration of the collective song archive. If the archive was ever at the very last slowest tempo, it would loop back to the fastest tempo and begin moving down from there.

Materials and Physical Form Design

Queue Player's physical form is comprised of a clear acrylic tube, polished maple, frosted acrylic, resin printed components, and 3D printed components. I chose these materials to give Queue Player the polish and robustness capable of enduring constant tapping from users over a significant period of time.

Next, I visually highlight and annotate the design iterations, and making process, and design events that occurred from initial ideations to the Queue Players' final form.

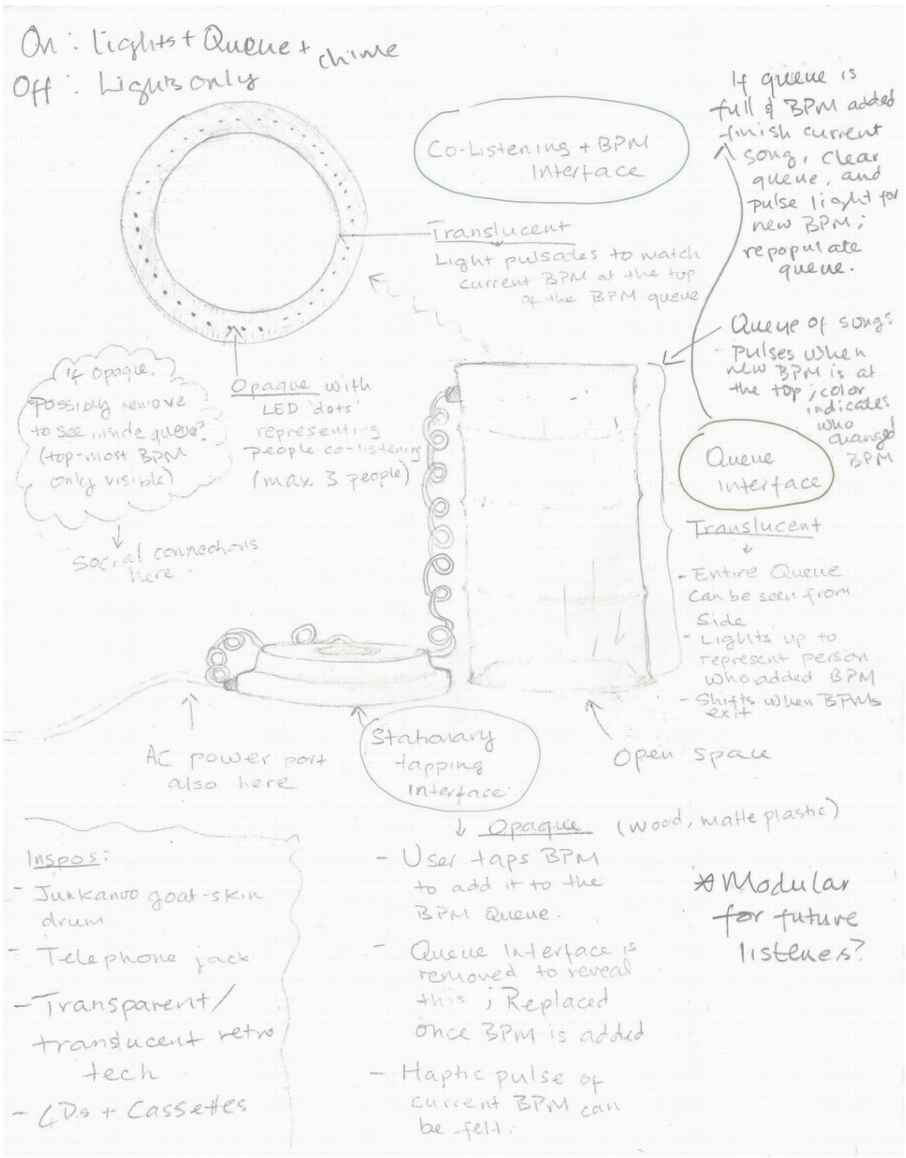


Figure 3.15 An early whiteboard drawing of Queue Player and different inspirations

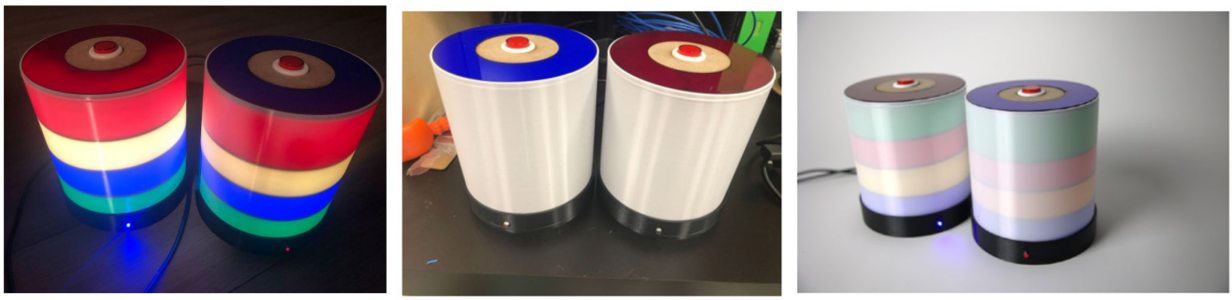


Figure 3.16 Early in the design process, I started with a proof of concept for the Queue Players. This was essential in determining form factor and size. I used an Arduino Uno microcontroller board to simulate Queue Player's light functions. Using white PLA filament for the 3D prints also helped to inform later iterations for diffusing lights. Here, I also tested light diffusion through glossy colored acrylic, and felt that too much light seeped through (see left). This design event, a *moment and transition*, influenced my decision to use frosted acrylic, which is not reflective, later on in the design process.

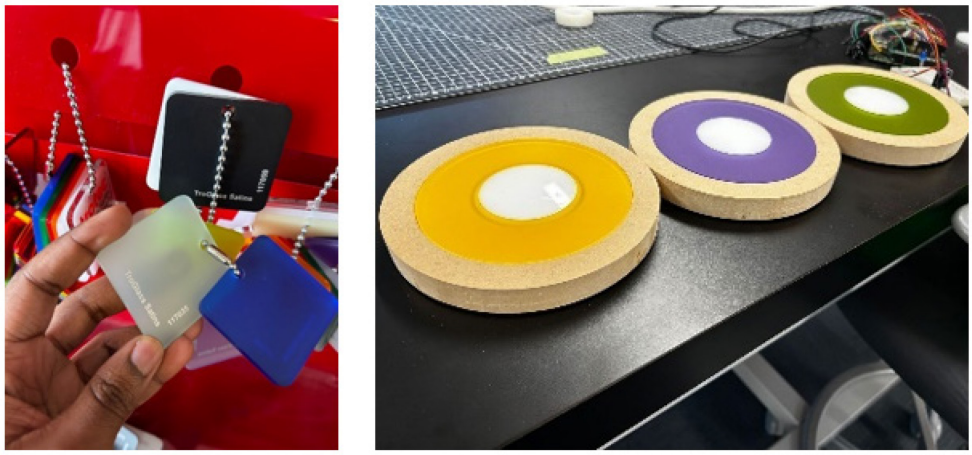


Figure 3.17 I explored different colors choices for the frosted acrylic, and eventually decided on yellow, green, violet and orange. Colors were also limited due to the stock local suppliers had, but I felt that these exhibited the colorful and vibrant spirit of Junkanoo very well. I also made early prototypes for the tops of the Queue Players by using CNC to cut and mill out MDF (see left). This allowed me to test how components fit together before moving onto the final wood version.

Figure 3.18 I designed a cylindrical core for to embed lights for the queue (see left). I also began to explore different forms and material options for a light diffuser. Early attempts used 3D printed PLA (see middle and right). Translucent filament resulted in undesired light refraction, while the white was much closer to want I pictured. However, I still felt that the ridges from the 3D printed layers were too distracting.

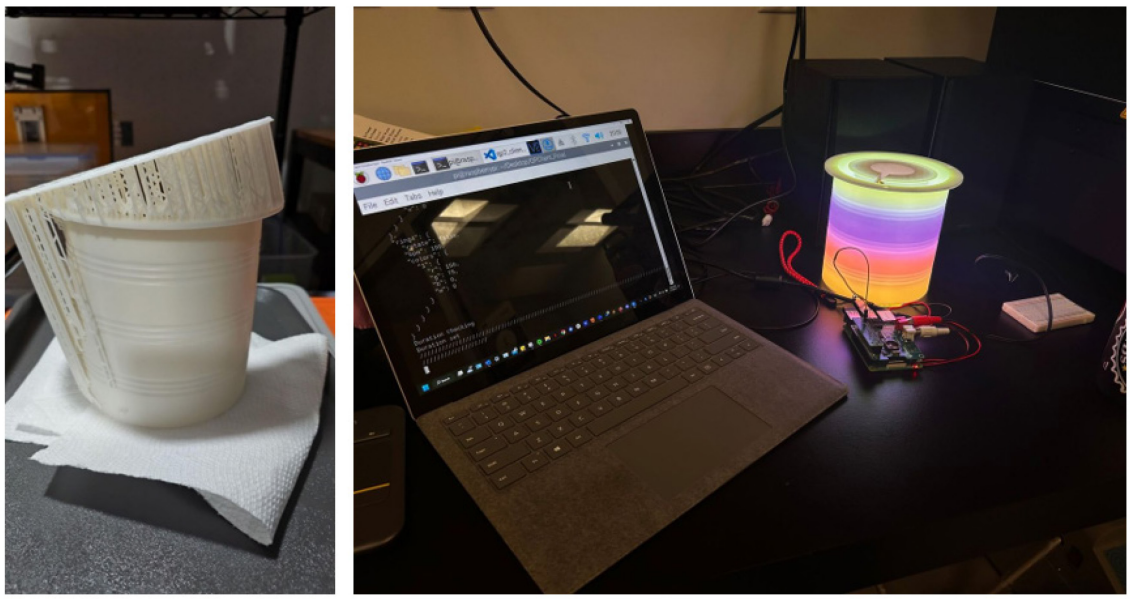


Figure 3.20 Resin printing the light diffuser gave a much better light resolution. After wet sanding with 400 grit sand paper I was able to achieve my desired light quality.

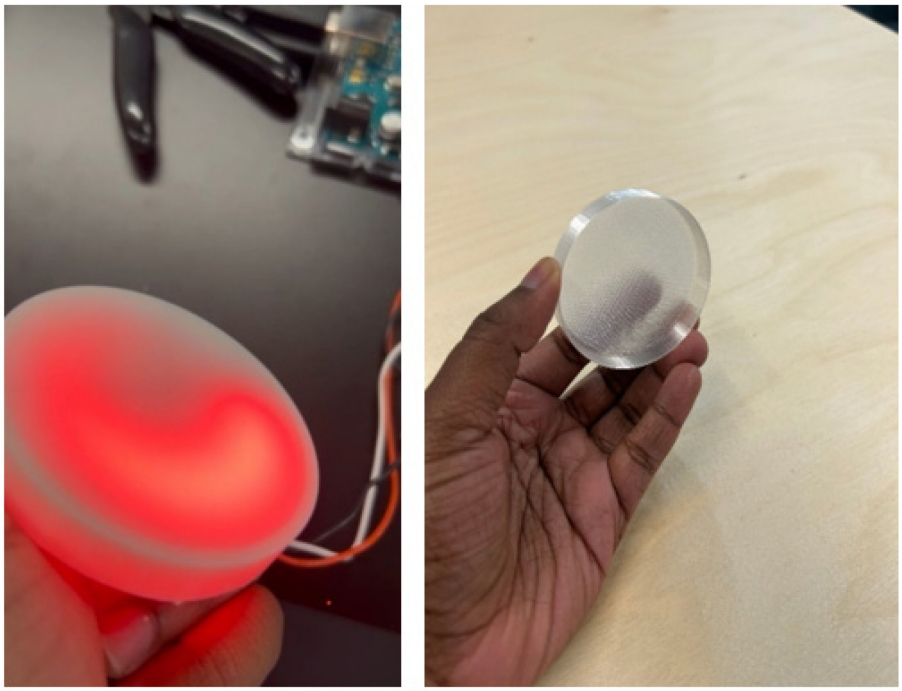


Figure 3.19 My first iteration with the ring light diffuser/ tapping interface was white translucent acrylic. This had a really nice feel and was an excellent diffuser. However, I was unable to accurately detect taps with the vibration sensor. This *encounter* led to a *transition*: the final iteration of a hollow, 3D printed disk, which was inspired by drums. The hollow body allowed more resonance and significantly improved tap detection.

Figure 3.22 I used the CNC to mill each of the Queue Player bases, base tops, and tops out of maple wood.

Figure 3.21 I then sanded all of the wooden components and drilled holes to mount the electronic hardware, knob, indicator light LEDs, and plugins for power and RCA.

Figure 3.24 Henry Lin and I also drilled holes to connect all of the Queue Player components together. This process was a major *encounter* and *pause*, as it took us a while to come up with the optimal solution for connecting everything. Drilling these holes also required a precision which had never been used for anything like this before.

Figure 3.23 I polished the maple using a glossy hardwax oil. Waiting for them to dry between coats was another *pause*. We were unable to move ahead with integrating all of the components until these were completely dry.

Figure 3.25 In the meantime, I moved on to cutting the acrylic tubes for each Queue Player's outer shell. At first, I tried to use our laser cutter to achieve smooth and uniform edges. However, it was difficult to do this without a rotary attachment. I ultimately used the bandsaw to cut the tubes, but was left with very rough edges. Using a propane torch to flame polish the edges gave me a much cleaner finish.

Once all of these components were individually refined and ready to put together, we faced several challenges and *encounters* with integrating everything. The maple was especially a problem. *Transitions* of working in the Homeware Lab, Solidspace (SFU Surrey's fabrication lab), and my home and Henry's, caused the wood to expand and contract multiple times over the design process as it was introduced to different environments. This caused the wood to split once everything was already CNC'd and polished, and also caused parts that fit before to not fit at all anymore. This resulted in numerous recuts and reprints to ensure that everything could come together properly. In the next section, the finalization phase, I describe the finalized version of the Queue Players as refined research products.

Figure 3.27 An array of all of the prototype iterations throughout the design process.

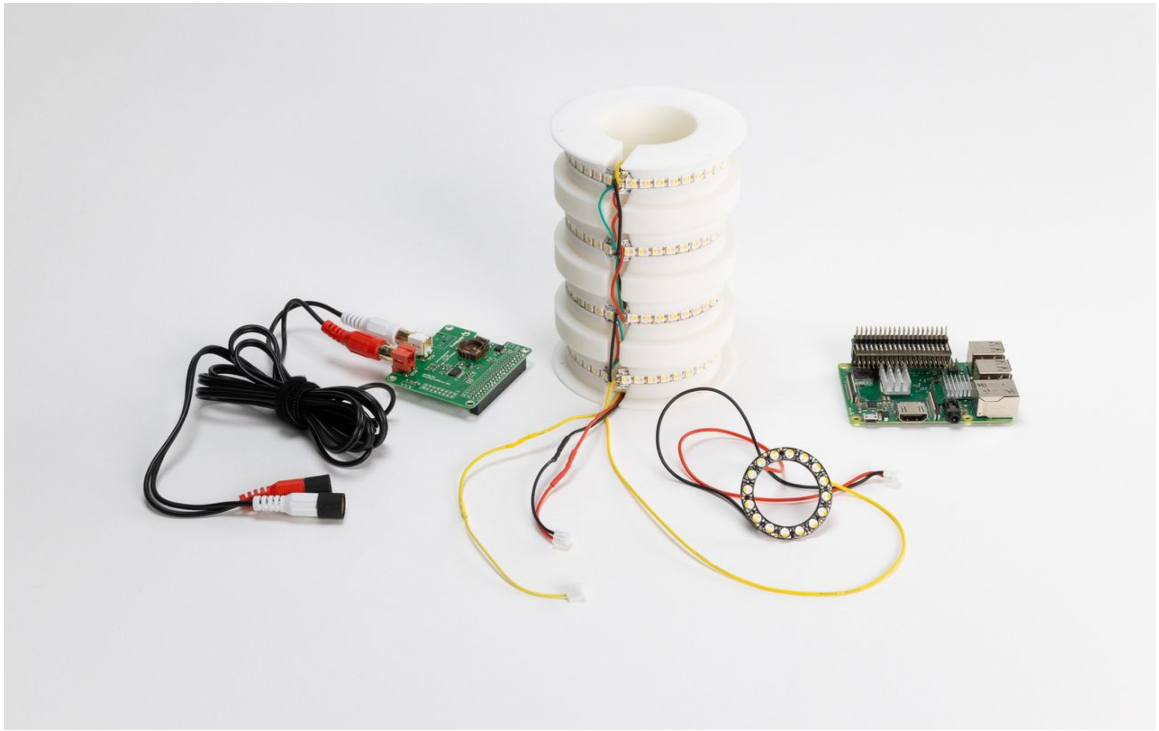


Figure 3.26 Hardware components used in the final Queue Player implementation.

3.2. Finalization Phase

3.2.1. The Finalized Form

The finalized form for the Queue Players consists of the following:

We implemented a Python script on a Raspberry Pi 3B+ to control all Queue Player functions. This script also connects each Queue Player to a centralized main server, which sends and receives messages from all of the Queue Players to maintain song synchronization and perform actions to indicate social presence (i.e., turning indicator lights on and off depending on which users are co-listening). As noted previously, the server also communicates with the Spotify API for song playback, and selects songs based on tempo inputs and machine learning cluster classifications. These songs are categorized by danceability and valence metrics to foster diverse listening experiences. A HiFiBerry DAC+ RTC board was used for Queue Player's RCA audio output and was mounted on top of the Raspberry Pi.

RGBW LED strips were used to represent a queue of songs, and users who owned them. They also indicate when a new tempo was introduced to the queue, and which user added the tempo. These lights were embedded into a cylindrical core with four evenly spaced sections (with 36 LEDs per section), diffused by a resin printed enclosure, and shone through a transparent acrylic tube. Knobs for power control were also resin printed. An RGBW LED ring was also used to indicate the current tempo through pulsing, as well as the color of the user who set the tempo. This light was diffused by a 3D printed hollow disc, which also served as a tapping surface for input interactions. Tapping was detected using a piezoelectric vibration sensor, which was mounted onto the hollow side of the 3D printed disc.

Maple wood was used for the top and base of each Queue Player. Because song data used was attached to specific users, each Queue Player script was distinctly specified to each user to allow them to experience and reflect on their own data within the combined archive. Frosted acrylic was used to assign colors to specific users, and four distinct colors were used overall: yellow, green, violet, and orange. The use of frosted acrylic also ensured that no light seeped through the top of the Queue Players.

Figure 3.28 The finalized version of four Queue Player Research products.

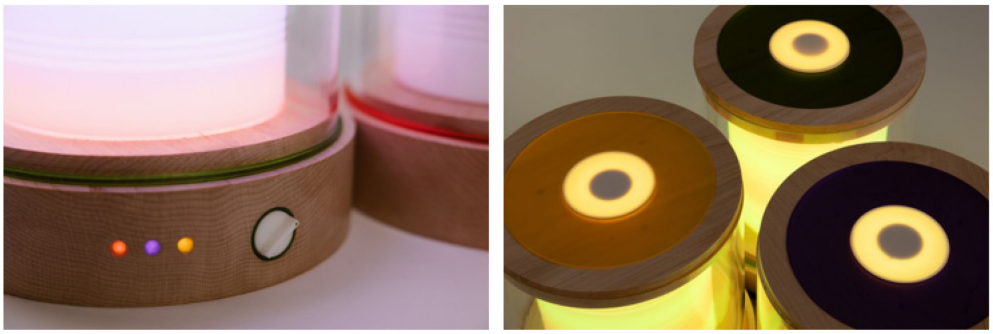


Figure 3.29 Examples showing the queue, indicator lights, and the tapping interface lit up.

Figure 3.30 The main components of Queue Player from left to light: RGBW ring light, core for RGBW LED strips, resin printed knobs, frosted acrylic tops, a transparent acrylic Tube, a wooden base and top made from maple, final electronic and hardware implementation, a 3D printed disc to diffuse the RGBW ring light

3.2.2. Usage Scenario

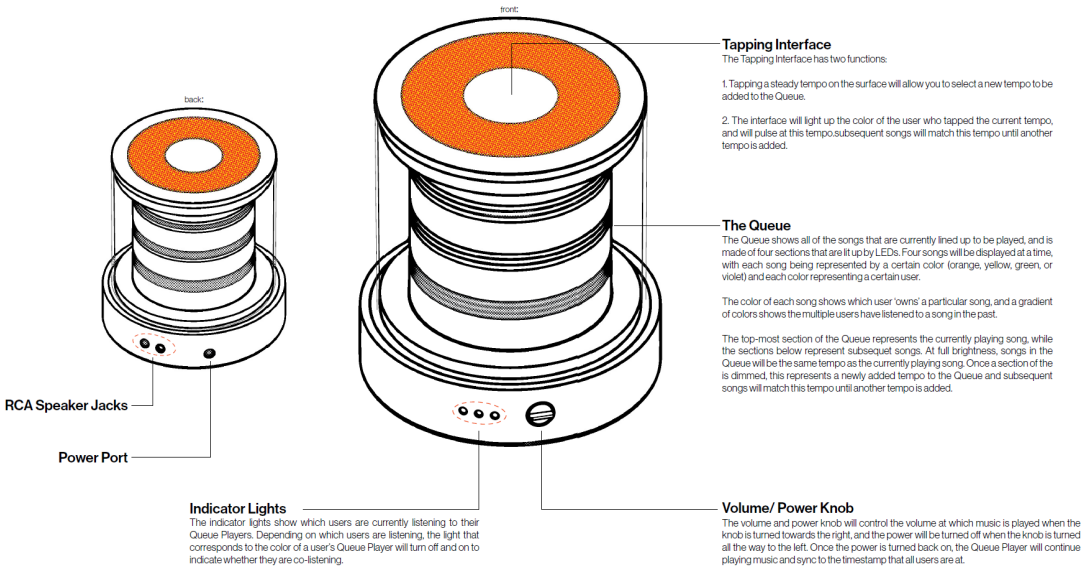


Figure 3.31 A diagram of a Queue Player and its features

Queue Players—a network of four tangible music players—act as a mediator between four users and a shared collection of their music listening histories. It allows them to engage in a co-listening experience and reflect on their listening histories both individually and collectively. For each Queue Player, its color corresponds to the specific user, to preserve their identities and ownership of their music within the archive. This color also shows up in a queue of lights, which represent upcoming songs and which user, or users 'owned' them in the past. The queue has four sections: the top-most section, which represents the currently playing song, and the latter three sections which indicate upcoming songs.

Once a user turns their Queue Player on, the queue is lit up and songs at a certain tempo populate the queue. If the user is the first/only person listening, the first song played in the queue belongs to them, while subsequent songs are selected from any other user. For a single user, the tempo of songs is arbitrarily chosen by the Queue Player, and is displayed through a pulsing on the tapping interface. The color of the light also corresponds to this user. From this point, the user has a choice between tapping a

new tempo for the queue, or leaving the queue alone to explore the songs currently available. If the latter is chosen, their Queue Player will continue to play songs at the current tempo until they are exhausted. Once this occurs, the Queue Player moves to the next lowest tempo available.

Once another user turns their Queue Player on, the first user will see an indicator light turn on, whose color corresponds to the user who just joined the listening session. The second user will also see the original user's light, and know that they are co-listening. For the second user, their Queue will be populated with songs that are already in the queue from the current listening session. At this point, they also have the opportunity to add a new tempo to the queue. If a tempo is tapped, the queue will clear all of the upcoming songs and replace them with songs that match the new tempo introduced. The second-most section of the queue will also dim to show that a new tempo has been introduced, and this song will come from the user who tapped. Once the currently playing song ends, the song from the new tempo will begin to play and subsequent songs will match the new tempo. This behavior is consistent with any additional users who join the listening session. However, once a user introduces a new tempo to the queue, they are unable to tap again until their current entry leaves the queue (i.e., the song is played).

Once a user turns their Queue Player off, their queue lights will fade to black. Other co-listeners will also see this person's indicator light turn off so that they can know that that person has temporarily left the listening session. However, indicator lights remain active no matter what a user's active state is. If a user's Queue Player is off, they are still able to see which users are actively listening, and can re-join the listening session whenever they want to.

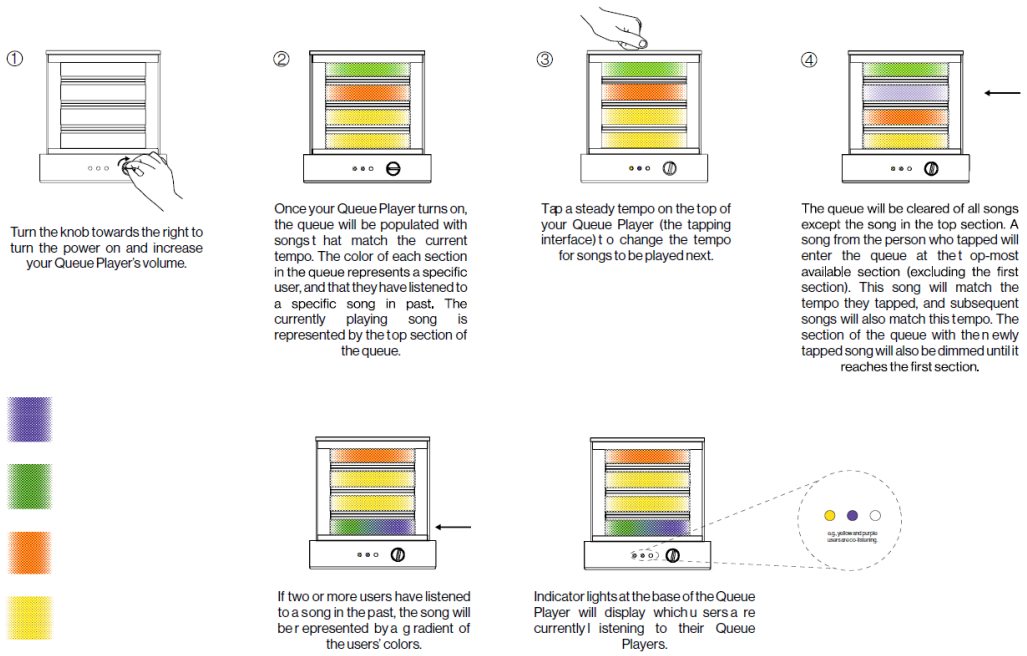


Figure 3.32 A guide to how Queue Player works

3.2.3. Participants, Data Collection, and Analysis

Study Method

My overall process was influenced by the concept of research products[53]– design artifacts that are created to drive a research inquiry and that have a high quality of finish such that people engage with them as is (i.e., a thing), rather than what they might become (i.e., a prototype). Research products are created to operate independently for substantial time periods to support long- term field studies in people's daily environments. Thus, as detailed above, we created a research product version of Queue Player to understand participants' experiences with it and how they might change over time. Following prior work (e.g., [7, 50, 52, 55]), 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.

With this framing in mind, I conducted a qualitative in-home field-study to explore how participants could use their Queue Players to explore their music-listening histories, and also experience synchronous and equally distributed co-listening together while living apart. One of the primary goals for this study was to explore how participants may 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 the tangibility of Queue Player could also 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.

This study and the Queue Players received approval from the Research Ethics Board at Simon Fraser University.

Participants

Recruitment

I recruited 4 participants living within Metro Vancouver, Canada to participate in a field study for Queue Player. Similar to the aim of Hutchinson et al.'s original Technology probes paper [31], the study focused on a small group of participants to gain a better understanding of the research space to inform future research and practice.

Given the novel quality of Queue Player that enables one to explore their listening history alongside a group of close friends or family members while living apart via co-listening, it was important to select a group of participants 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' [32, 61, 75, 85], we ensured that the participants selected were also people that I, as the student lead researcher, knew. Thus, recruitment for the study was conducted through word of mouth. Taking this approach for the field study had several benefits:

1. **Immersion and Informal Engagement:** Deep hanging out allowed me to immerse myself in the Queue Player experience alongside the participants on

an informal level. This facilitated on-going engagement, enabling me to observe and participate in their interactions naturally.

2. **Observation of Social Dynamics:** I could observe broader social dynamics and relationships among the participants, providing insights into how their friendships influenced their music-listening behaviors and co-listening practices.

3. **Contextual Insights:** Observing the participants in their homes provided contextual insights into how they interacted with their Queue Players. This helped me understand different aspects of their experiences, such as the influence of physical environment on their listening practices.

4. **Meaningful Insights:** The informal and ongoing engagement with the participants allowed me to uncover more meaningful insights. I could observe spontaneous reactions during one-on-one listening sessions and a group interview, which revealed deeper emotional and psychological responses.

5. **Vulnerability and Honesty:** The existing relationships between the participants and myself prompted more vulnerability and honesty about their experiences and listening practices. This connection allowed for insights that might have only been possible among those with a shared history, leading to a richer and more authentic understanding of their interactions with Queue Player.

We also ensured that the participants selected had Spotify Premium accounts spanning at least three years, to provide a rich and diverse database for Queue Player to draw from and for participants to experience and reflect on together.

All participants and I have known each other for at least two years. They also had varying levels of closeness with each other, which made for rich reflections, and diverse experiences between them throughout the study. They were also compensated with 100 CAD for their participation in the study. In this thesis, I will use pseudonyms to describe and refer to the participants.

Participants and general orientations towards individual and social music-listening

To better contextualize the themes presented in the findings section, I give brief vignettes of each participants and their general music-listening practices, and their feelings towards sharing music with others.

Participant 1, Florence:

Florence is in her early 20s and lives at home with her parents. She primarily works as a literacy tutor for children with Dyslexia. She is ethnically Filipino, but grew up in Metro Vancouver, Canada.

For Florence, music has always played a significant role in her life. Her dad introduced her to a lot of music growing up, for which she credits her openness towards listening to various genres of music and her inclination to cater to others' musical preferences during shared listening experiences. Her Spotify account spans approximately 6 years, and is shared with her family members. Her portion of the collective archive included 20,537 songs.

Figure 3.33 Florence Using Her Queue Player (Yellow)

Participant 2, Julian:

Julian is in his early 30s and lives in an apartment with one roommate. He works in patenting at a research development company in Vancouver, Canada. He grew up in Houston, Texas and is ethnically Mexican-Chinese.

Growing up, his parents had very different tastes in music, with his mom listening to more psychedelic rock, and his dad listening to a lot of experimental and ambient music. His dad's frequent travels also exposed Julian to music from various cultures, and this largely influenced Julian's appreciation for unique sounds and instrumentation. It also sparked his love for shared experiences and exploring others' music tastes. Julian's Spotify account spans over 10 years, and his portion of the collective archive included 8069 songs.

Figure 3.34 Julian Using His Queue Player (Green)

Participant 3, Gregory:

Gregory is in his early 30s and lives in a household with his landlord. Gregory was born and raised in the Philippines, and is ethnically Chinese. He works in a financial firm as an insurance specialist in Vancouver, Canada.

Growing up, Gregory primarily listened to the radio that played from his neighbors' backyard, where the music genres ranged from OPM (Original Pilipino Music) to 70s American music. Gregory's desire to discover new music stemmed from these experiences, and has led to open and adventurous listening to music with Spotify. Gregory has had his Spotify account for at least 5 years, and he had 23,122 songs in the collective song archive

Figure 3.35 Gregory Using His Queue Player (Violet)

Participant 4, Kassandra:

Kassandra is in her late 20s and lives in an apartment with one roommate. Kassandra was born and raised in Burnaby, British Columbia, and her parents are from Switzerland and Austria. She works as a receptionist and makeup artist in Metro Vancouver, Canada.

Though her parents' music tastes influenced a lot of the music she listened to, Kassandra was also a dancer growing up. Dance introduced her to a lot of different music genres, and allowed her to explore how different types of music made her feel through embodiment and storytelling. She views dance and music as forms of communication and connection. Sharing music and dancing with friends are, for her, profound ways to find common ground and foster intimacy. However, she also finds that listening on her own also gives her the space to experience and enjoy music without external biases or pressures. Her Spotify account spans approximately 6 years, and she had 14,542 songs in the song archive

Figure 3.36 Kassandra Using Her Queue Player (Orange)

Participants as a friend group

When considering the participant constraints for the study, I felt that my church would be the best place to recruit participants. After approaching **Kassandra** about participating, she then suggested **Florence, Julian, and Gregory** as other potential participants, as they all knew each other pretty well and also met the study criteria. It also worked out that I knew them all as well.

When I inquired about their history as a friend group, they noted that there were varying degrees of closeness between them. For instance, **Kassandra** and **Florence** have known each other since their teenage years and regularly spend time together, while **Julian** and **Gregory** share a closer friendship and hang out more often themselves. Kassandra and Florence's friendship spans over 10 years, and the overall group has known each other for approximately 6 years. I met them all through church and have known each of them for approximately 2.5 years. Despite these varying levels of closeness, the participants have all engaged in many shared activities over the years, such as group Bible devotionals, dinners, parties, road trips, hiking trips, and game nights. I have also participated in many of these activities with them, which made for promising group dynamic to explore throughout the study.

Conducting the Study

Before the study took place, I asked each of the participants to request their 'Extended Streaming History'[13] from Spotify, which includes all of the songs, videos, and podcasts that a user has listened to during the lifetime of their Spotify account. I also set up a WhatsApp group chat between the participants and myself to share our thoughts and experiences throughout the study.

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. We provided each participant with a Queue Player that was connected to a shared remote server once it was plugged in.

[13] https://support.spotify.com/ca-en/article/understanding-my-data/

Figure 3.37 Binding the booklets for the field study.

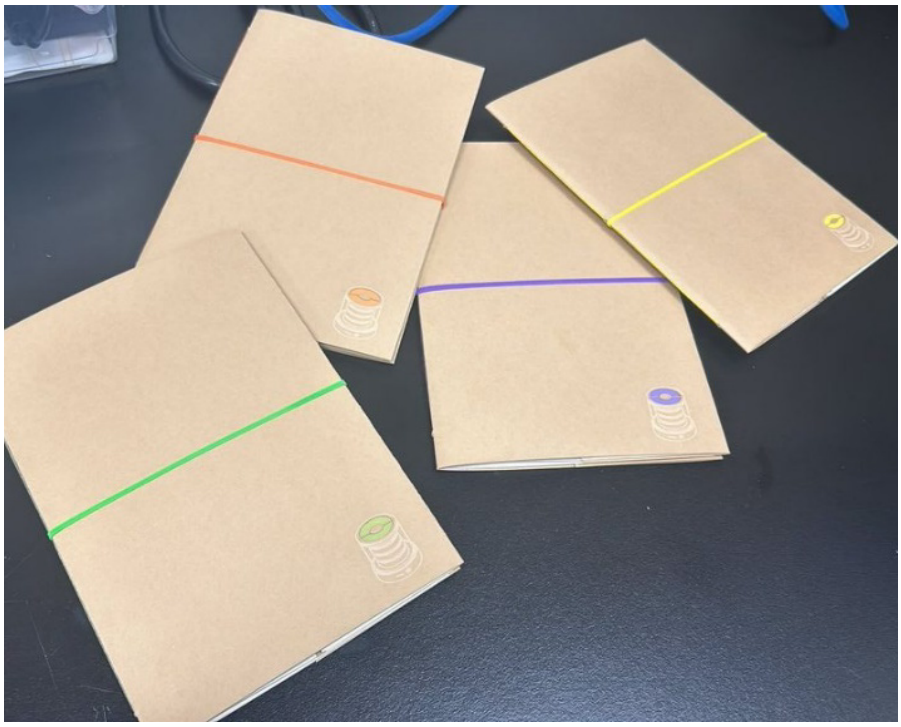


Figure 3.38 Final field study booklets given to each participant.

During the initial visit to participants' houses, we focused on developing and understanding of the participants' daily lives and practices. Two of the participants (Julian and Kassandra) chose to situate their Queue Players in their living rooms, while the other two (Florence and Gregory) placed theirs in their bedrooms. We also provided the participants with external speakers, which they used for audio output. We then gave a demo of how Queue Player works, and shared a field study booklet **(see Appendix A.)** that further explained how it works and included prompts on how they might use their Queue Player throughout the study. The booklet included a notes section for them to write down any thoughts or observations they had during the study. We also told participants that they weren't required to interact with their Queue Player, but encouraged them to develop their own understanding of and sensibility towards living with it and interacting with it as a part of their daily life. This gave them the freedom to engage (or not engage) with the device as often as they chose. We informed participants that they could drop out of the study at any time.

After installing the Queue Players and demonstrating how they worked, I conducted a 15–30-minute interview **(For sample questions, see Appendix B.**) to get sense 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.

After the initial visit, I conducted weekly listening sessions over the course of 4 weeks, where I was able to visit one participant's house each week. For each session, I would have an informal hang-out with each participant to get a sense of their experience with their Queue Player (**For sample questions, see Appendix C.**). Both on an individual level, and as a part of the group. These sessions were audio recorded, and lasted anywhere from 60-90 minutes. The other three participants also listened on their ends simultaneously, and often shared their thoughts in our WhatsApp chat. After each listening session, I made fieldnotes with impressions, key quotes, and notable moments observed during the session.

During the final week of the field study, the participants, myself, and Will Odom all met in person at the Homeware Lab for a final group interview. This interview lasted around 90 minutes, and focused on the participants' reflections on the study, their experiences using Queue Player, their 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. I also presented them with a zine as a parting gift that served as a souvenir from the study, as well as an alternative way of conveying their individual and combined listening histories to them (**see Appendix D.**)

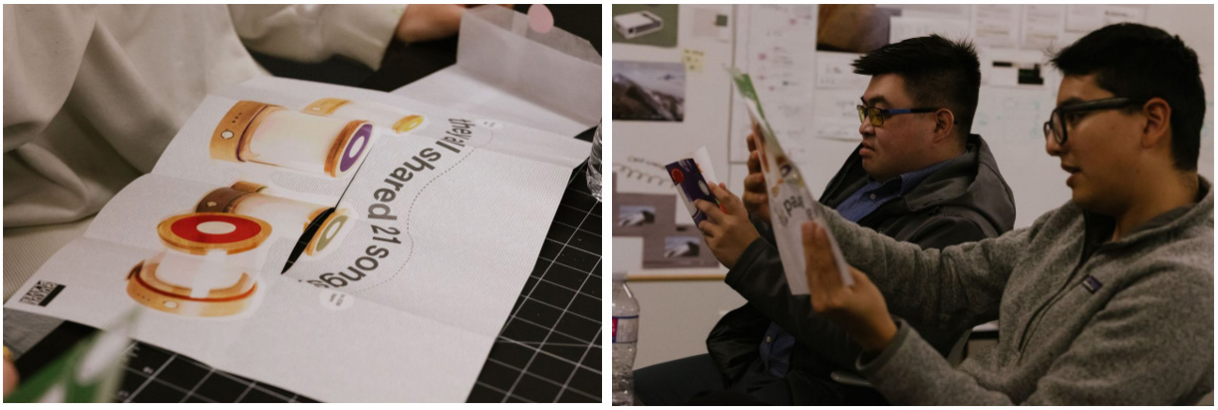


Figure 3.39 Participants opening and reviewing their zines during the final group interview.

Data Analysis

For analyzing the field study data, we often referred to fieldnotes and recordings that captured participants' earlier experiences to explore possible individual-level and group-level changes in their attitudes toward Queue Player. All interview sessions were audio recorded, and relevant segments of recordings were transcribed. Field notes I took were reviewed immediately following each listening session and interview, and tentative insights were noted in reflective field memos[21]. Analysis of the data was an ongoing process. After each visit to participants, I, along with my supervisor Odom, conducted a preliminary analysis, searching for emergent, stabilizing, and shifting patterns across our data to draw out underlying themes [44]. We coded raw documents with these themes. We also created affinity diagrams to model connections and differences among participants.

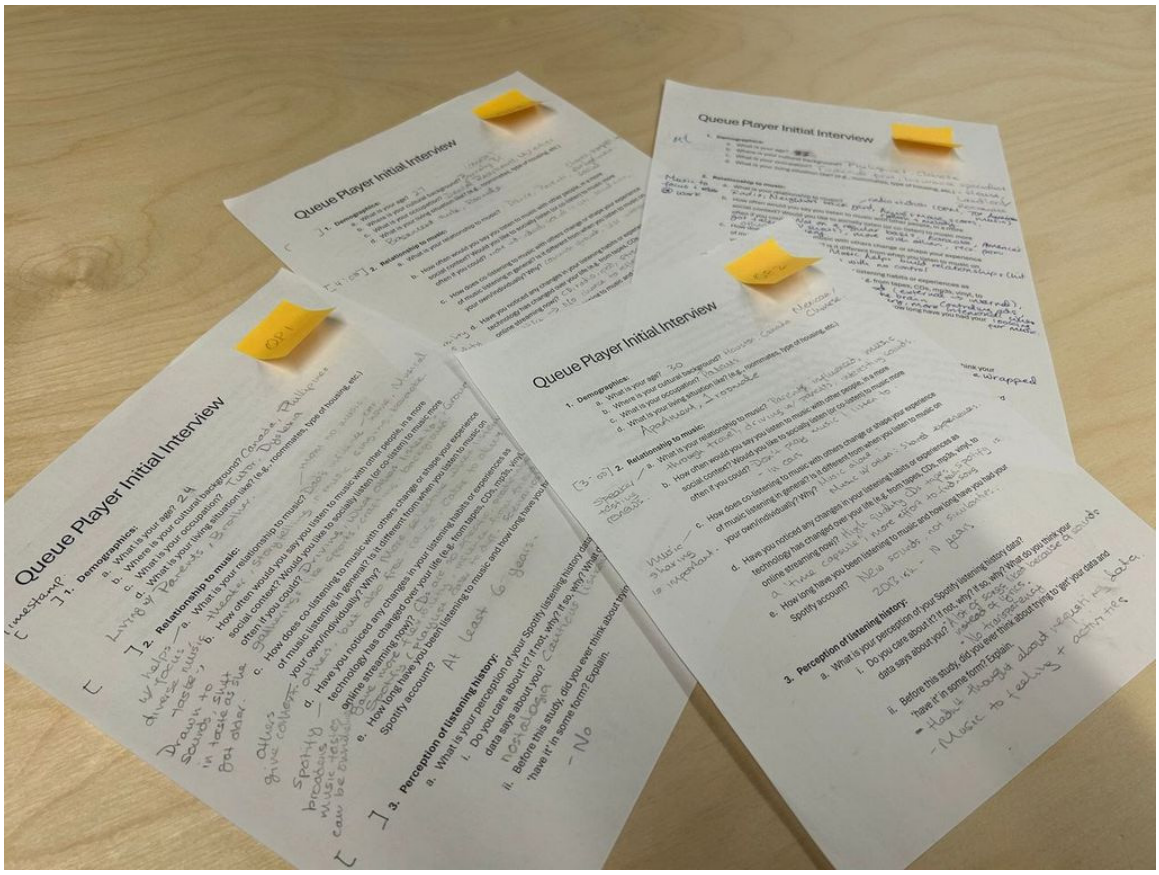


Figure 3.40 Field Notes Taken During the Initial Interviews

Chapter 4.

Findings

Next, I 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.

Figure 4.1 Moments with participants during the Queue Player field study

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

When I 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 was a recurring theme that also emerged during initial interviews, where participants shared anecdotes about their upbringing and how various experiences influenced both their music tastes and attitudes towards sharing music with others.

Julian's reflection in our initial interview encapsulates his past experiences with sharing music and how they shaped his social listening practices:

> "I find my music taste can be polarizing. A lot of people don't like the music that I listen to. Growing up, my mom didn't like my music. So generally, if I'm listening to music with other people, I will not play the songs that I usually listen to. I'll make other playlists of songs that I think they will enjoy."

Julian revealed how he often curates the music he shares with others by selecting songs he believes they will enjoy, rather than those he would typically listen to. He further went on to discuss how, upon reflecting on his past listening habits, he recognized that some of his songs might affect the group and expressed a hesitance to disclose his history:

> "I [am] a little apprehensive because like, I know, some people can find certain lyrics offensive. There are lot of A$AP Rocky songs I really enjoy because it reminds me of a certain time in my life when I was at school. But I mean, many of them have, like, very misogynistic lyrics. And they talk about criminal activities and stuff. Like, that could be triggering to people, and I recognize that."

Gregory expressed similar anxieties with disclosing some of his listening history to others. During his listening session, which was the third listening session in the study, he discussed how Queue Player led him to consider and experience the breadth of his listening history data and how it might be perceived by others:

> "[With] certain people, I would say I'm still kind of repressive [with] my data, like I want to be keeping it to myself. There are things [that] I would like to still share. It really depends on what that data would be. [With] certain

> songs… I'm okay sharing certain songs. [With others] I think “Oh, I should have deleted that.”

Florence’s reflection during her listening session echoed this apprehension, but also highlighted a shift how she approached listening to her music and thinking about her data through using Queue Player:

> “I think [this experience has] made me more cautious now of what I choose to listen to. I've always been like that, but now I’m extra [cautious]. Because I'm like, oh yeah, what I listened to, there's data for that. There's a history of what I've listened to.”

By relinquishing some control over song choice to Queue Player, we intended to encourage sharing music with an open mind, foster open discussions around listening histories, and to potentially add more depth and social context to participants’ lives through co-listening, all of which I saw happen throughout the study. However, I found that as the study went on, participants became less concerned about which songs would play, and increasingly aware of what their listening history data actually is. The lack of control in song selection prompted participants to ruminate on how and when their listening data is collected by Spotify, and what their data ultimately says about them.

While **Florence** had already described herself as a cautious listener, by the end of the study her perspective evolved into an awareness of self and a consideration for future listening habits:

> “I think, for me, I became a lot more cautious and self-aware. Like, what am I about to play now? What am I gonna search up? Not that I have stuff to hide, but it's more just like, “oh, do I really want that in my history?”

One of the key goals for this study was to examine how people might perceive their data once it is presented to them in a physical form in their everyday life. Queue Player allowed participants to ‘have’ their data while it was once intangible and inaccessible. However, limiting control in Queue Player ‘s song selection provided space for participants to shift their thinking away from anxieties with disclosing their music to others, to critically reflecting on their data over the course of study. Participants were also able to adjust to the experience of having parts of their histories disclosed as they developed more familiarity, trust, and understanding of each other over the course of the study. By the end of the study, I found that participants were able to joke and laugh

about experiences that they had while co-listening, and also consider future interactions between them when sharing music.

4.2. Re-encountering Listening History Data

4.2.1. Experiencing Nostalgia and Contextualizing Listening Data

During initial interviews, I 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. I think that's the one of like, 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. So sometimes I'll go back, like to the beginning of my likes playlist. For example, the first song that I added to it. What year was that? What kind of headspace was I in?"

When I probed her about this after the study concluded and she had lived with Queue Player for considerable time, I noticed a 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."

Before, she would consider why songs were significant to her at the time. However, 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 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, I asked each of the participants to request their extended streaming history from Spotify to create the song database that the Queue Players would pull music from. However, no participants were aware that their data could be requested. **Julian** expressed his thoughts on the extensive mundane history of his music listening data that is now captured and contained by during our initial interview:

> "Spotify is something that is kind of part of my ordinary life, it's just something that's kind of part of a habit of listening to it. And so, I don't really think about the fact that my data is being used because it's just normalized. So, I think maybe that's why it could be surprising if you realize they've been [collecting] 10 years of data[…] They've told me upfront but yeah, you don't really think about that."

This revelation opened up opportunities to probe participants about their experiences with now 'having' their Spotify data in a tangible and easily accessible form. During initial interviews, I also asked participants what they thought their data might look like, in terms of reminiscing as an individual and experiencing their data mixed in with everyone else's. They each had ideas about their data, with Florence and Kassandra bringing up two interesting points that reflected both intrigue as well as ambivalence:

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

> "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." (**Kassandra**)

Florence was confident in her data's predictability, despite sharing her Spotify account with her family. On the other hand, Kassandra expressed uncertainty about her data due to external factors like Spotify's song recommendation algorithm.

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. When collecting all participants' respective data, preparing it for the song archive, and extensively testing the Queue Players with it, I also considered each person's dataset to be their own without really taking outside influences into account. However, in **Julian's** listening session, his reflections on his data pointed towards 'imperfections' and 'impurities' in the archive:

> "Sometimes others will borrow our accounts. […] Because there were times when, just having roommates, they would play songs on the sound system. And that that's like a whole different profile of songs that are on the [Spotify] account from that."

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** often mentioned in our WhatsApp group chat that certain songs belonged to her brother or her dad (**see Fig. 4.1**). In his listening session, **Gregory** recalled having friends use his Spotify account during road trips to play music as he drove.

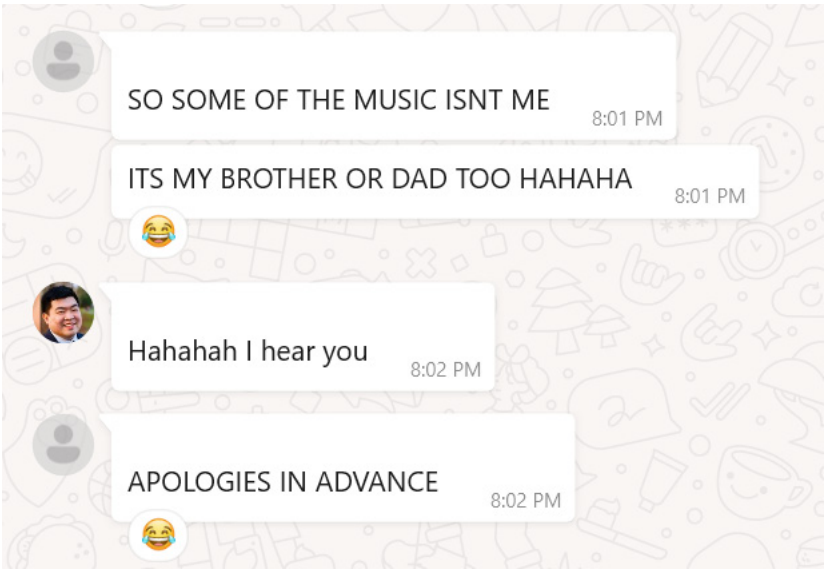


Figure 4.3 Group chat messages with Florence expressing that some songs did not belong to her.

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's** summarized this well during the final group interview:

> "We kind of recognize what we think is our music. It's really interesting because I am still skeptical. I don't trust that is necessarily [entirely] our music. But if it is certainly, you know, 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."

He elaborated further on this, and expressed how inaccurate datasets could lead to false perceptions of others and self:

> "You can learn a lot about someone by the type of music they listen to, especially when you know the significance behind them. I think that's one of the reasons why it was kind of jarring when a song lit up for me, but I don't I didn't recognize it. It's just like, people are going to think something of me that's not true. It's saying something about me that's not actually accurate because I don't recognize a song. It's kind of interesting, just, I guess how we think others might perceive us by our music tastes."

All of these reflections from participants revealed a distinction between perceived and actual listening histories, but **Julian** really highlighted that while listening histories are imperfect, they are also incomplete:

> "I'm also just realizing that many of the songs that we've all heard before, we haven't clicked on Spotify, and we've heard them somewhere else. So, the songs we actually all know are probably a lot higher than what Spotify represents. So, like in terms of songs that we expressly want to listen to, we've sought out on Spotify. Maybe [the data] is not surprising because it is sort of such a broad spectrum of genres and artists."

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. Early in the study **Julian** shared his thoughts on what types of connections he thought could be seen between him and the rest of the participants:

> “Through conversation, you could uncover the same types of things. Like, you know, we've listened to these songs before, but it would be incredibly slow.”

Here, Julian suggested that Queue Player was mediator between people’s real and ‘masked’ identities, as it allowed everyone to form new understandings of each other.

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 progressed *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. But I kind of think, like, what does he like about this? And 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?”, which is cool.”

Julian (during his listening session) and Gregory (during the final group interview) shared similar reflections around the broadening of music taste and understanding others through their music:

> “I like the fact that I get to listen to all types of music that I wouldn't generally choose to listen to, not that I would dislike it; I just I didn't know it existed. And it's fun that it's music that in a way does have significance because everyone has listened to it at some point, whether or not they deliberately clicked on it or not, which is cool.” **(Julian)**

> “It's really great to see other people's music tastes. That's why I prefer seeing other people's because I want to get to know them better. Not that I'm hiding my songs, but it's more like, I want to get to know them better.” **(Gregory)**

Throughout the study, Queue Player also prompted participants to interact with each other about songs of interest, and different observations during the study **(see Fig. 4.4)**. Again, Kassandra shared her reflections on this:

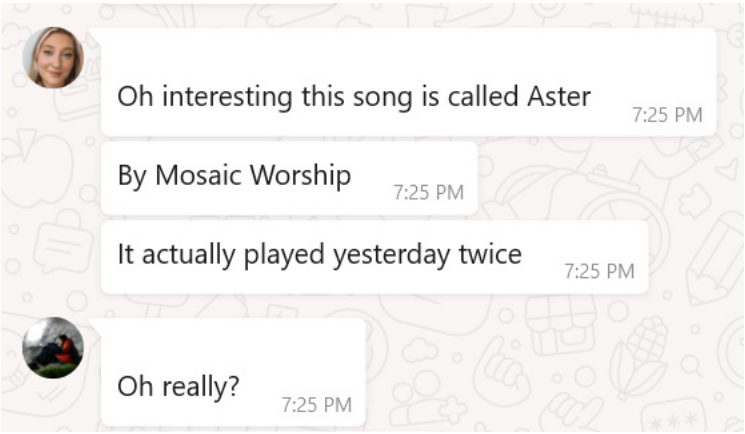


Figure 4.4 Group chat messages about things that occurred while listening with Queue Players.

> “I think it's been fun. I like having it on just like while I'm doing stuff in the house. And then like, we'll try to text each other. If we have a song that we like, or we're surprised by something that someone else listens to…it just brings in like an extra little interest. Like, interesting element to the day.”

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 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."

Florence also shared final thoughts on how using Queue Player had impacted her relationship with each participant and unveiled implications for her future music listening experiences:

> "I know [Kassandra] pretty well, but like knowing you guys (Julian and Gregory), and then knowing more of you guys through your music taste, that was cool for me. [...] I feel like in the future when I listen to whatever song, it'll make me think of like, 'Oh, I think Gregory might like this.' Or like, 'Oh, maybe Julian would like this' in a way, kind of knowing each other's preferred genre and stuff."

Queue Player enabled participants to have an explicit awareness of others and their listening habits through the queue, and also 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

Gregory also discussed how he perceived that getting to know the other participants through using Queue Player, and more specifically, through observing the queue, could lead to a range of interpretations:

> "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 and making assumptions of what would play based on what they previously heard and experienced from certain users resulted in experiences like Gregory’s as they developed a better understanding of each other. When designing the interactions for Queue Player, *implicit slowness* also 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 I observed how participants would often use 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 others ‘profiling’ his music, however, points to an interesting dynamic: while music sharing can foster deeper understanding and empathy, it can also lead to certain assumptions about others based on their music selections. His reflection also ties into individual and social expectations about data once it is shared with others.

4.4. 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 influence their use of Queue Player. They

expressed that knowing when others had their Queue Players on encouraged them to co-listen as well. **Florence's** 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". Sometimes I'll turn it on when someone else is [on and] we're both listening. It's like a sense of "we're sharing this together". Like, we're not together but I feel like we're together."

Kassandra also noted similar experiences, highlighting how the tangible aspect of Queue Player fostered a sense of connection with the other participants:

> "Only usually when I see the lights, the little ones, [I feel the presence of others]…A lot of the time I feel like I'm the only one listening because I don't see any of their lights on. However, I do feel a sense of awareness when I do turn it on in general. Because I know that it's an accumulation of all of our libraries. I do feel a sense of when we're all listening that they would hear what I hear. It's kind of like we're all looking at the same moon from different sides of the world."

Participants shared in Kassandra sentiment, and their appreciation for each other's presence was evident during listening sessions, both in verbal responses and through messages in our WhatsApp group chat **(see Fig. 4.5)**.

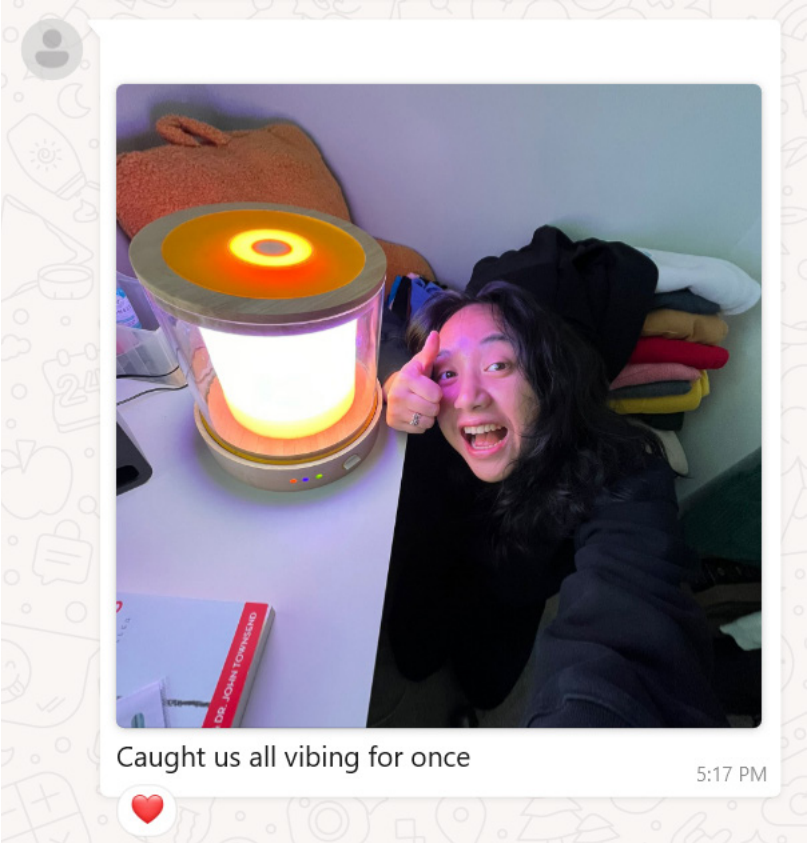


Figure 4.5 Group chat message showing all participants tuned into a listening session together.

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:

> "There are times where and if I'm with only certain people, I don't actually tap at all. It's only when everybody's there that I'm like " okay, let's mess things up."

During his listening session, Gregory's reflection that sharing music provides opportunities to learn about and better understand people through their listening habits

suggests he viewed listening with one person at a time as a chance for bonding and developing individual understanding. In contrast, group listening sessions were possibly seen as opportunities to explore the archive more extensively together.

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:

> "I think it had just increased my, I guess, awareness. And like, I guess tolerance [of] other music. I think it just enhanced it; I would say… like my curiosity to new music. [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. Yeah, nowadays 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 disrupt others:

> "I did appreciate it when people [would] listen to [my songs] completely. Like not switching songs. But there were times where I didn't want other people to listen to my song per se. Because some people were like, asleep or about to sleep."

> "Usually when I [turn on] the queue player, I don't like slow music because I'm doing stuff. But it could be that at their particular time, what they're [one of the other participants] doing is they're actually meditating or something. [The music] could be disruptive, but it can also be energetic. You can control the mood of the room."

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.

4.5. 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 rouse her into a more upbeat activity:

> "I think something also that I noticed during one of the listening sessions is that I'd have [the music] play in the background, and then [I'd be] doing my own thing. And then I think at one point, it was just a lot of like, slow music and stuff. And so I was, you know, doing a very slow activity and I think my mood kind of catered a lot to like what I was doing [...] And then it, like, changed the tempo[…] And I felt compelled to be like, "Okay, I gotta do something else". Like, I couldn't do this silent activity anymore[…] It didn't make sense for me to keep doing that."

This was an exemplary account of Queue Player's potential to create opportunities for social bonding and intimacy between co-listeners by allowing them to mirror each other's feelings and activities based on particular tempos or the valence (i.e., the emotional quality) of songs.

Gregory shared reflections on using his Queue Player as a grounding element:

> "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 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.

4.6. 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 like, interestingly enough, with the increase of accessibility there's a decrease in well, slowness and meaningfulness perhaps, and intentionality. It's a little bit different in terms of experience. You know, before it was it was more, like, 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, I want to decide 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 older music-listening media. It also highlights the potential slow technology has to re-instate 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 is evident in how, if left untouched, songs continue to play based on the current tempo until it is exhausted. Tap tempo was intended to 'speed up' the rate at which the archive could be explored. Explicit slowness is what required users to wait for songs to play to completion and also wait for a new tempo to be explored once a user introduced it to the queue. Before the study began, none of the participants were familiar with slow technology, and the design decisions around integrating implicit and explicit slowness resulted in frictions for participants 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. So, there have definitely been times when I really wished I knew what a song was. […] Another aspect is that 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."

While implicit and explicit slowness were used to create a minimal design encouraging reflection and interpretation through listening, they invoked tensions among participants. Particularly, the ability to look up songs was something we never intended with Queue Player, but its absence added a layer of frustration for all participants. Despite this, **Julian's** reflection later on in his listening session showed a shift towards becoming more self-aware, worrying less the specifics of a song (e.g., seeing it on a screen), and being present:

"It does kind of force you to just be present. think it in that way makes it more enjoyable because you just got to kind of be in the moment and be present and listen to it and enjoy it, not knowing when it could end."

Florence had a similar account during the final group interview:

> "Sometimes when I'm listening to my Queue Player it's like okay, "oh, those are the lyrics of that song"[…] I think I was able to really engage myself and be more present in what was being said or like or even just catching little things of like, "Oh, I didn't know that song had that little ad lib in there." You know, just little details like that."

Early on in the study, Julian faced tensions between the known and unknown while listening to songs through Queue Player. However, Julian and Florence 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. And I think it is kind of a neat experience to listen to music that I wouldn't choose to listen to typically. And to kind of like have to give a chance, and to kind of reflect on like, you know, why

> don't I usually listen to [this] music? Or why don't I like it? That's something I wouldn't experience if I were just searching songs as I like."

Here, the shift in Julian's attitude towards slow technology exemplifies it's potential to broaden exposure to music and encourage reflection on personal listening habits. By fostering a more present and mindful approach to music consumption, Queue Player reveals the value of implicit and explicit slowness in enhancing the depth and richness of listening experiences. Julian's reflection also touches on the dynamics of intimate relationships. Often times, one has to compromise something to allow a relationship to grow and progress. However, such cases often provide insights into new worldviews, perspectives, and diverse experiences that can impact individuals and their relationships for the better.

During our final group interview, **Kassandra** 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, kind of, you know, to make our lives easier, more enjoyable. And I think that it kind of actually […] can kind of cater to this robotic kind of pattern in terms of, consumerism and all of that.
>
> […]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."

Kassandra's reflection highlighted her realization that slow technology can offer significant advantages to people's lives through everyday devices. However, the tendency of modern technology to prioritize fast-paced and immediate interactions is a significant obstacle that first needs to be addressed.

Chapter 5.

Discussion

As the capabilities of music streaming services evolve, exploring one's past listening habits becomes paramount as digital music accumulates into a large historical archive. Prior work has shown the rich possibilities that materially present forms of one's listening habits has for revealing insights into how people can reflect on their personal data and history through different temporal modalities [5, 47, 51]. Similar insights have also been presented through other media such as personal photo, location, and hiking data [6, 7, 48, 54, 73]. However, these works have exclusively examined the exploration of individual histories and leave room for new insights into the reflective potentialities of socially combined personal histories among loved ones.

Findings from the Queue Player field study suggest rich possibilities for people to revisit their listening histories through co-listening with those they already share close a relationship with. This builds on Odom et al.'s extension [49] of the original, highly aspirational slow technology design qualities [24], 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, the Queue Player field study reveals renewed potential for deeper social connections and personal insights through the collective exploration of music archives. Next, I present considerations for HCI and design communities that emerged from our work.

5.1. Designing for Data Autonomy, Anticipation, and Long-term Interactions

Queue Player leverages the listening history data of four friends, with a database transformed from four distinct and unique listening histories into one collective social archive. Initially, this was disorienting for participants as they were confronted with their data interconnected with three of their friends' data. Early on, participants also experienced anxiety over the potential social disclosure of their listening histories, exacerbated by the lack of control over which songs would be played. This anxiety was

rooted in concerns about how their personal listening history data might be perceived by others. Participants' apprehensions suggest that if they had some knowledge of what their data looked like outside of a social context, it might have lessened the anxiety felt when Queue Player surfaced their songs. On the other hand, introducing participants' data in this way did appear to stimulate anticipatory and curious listening experiences, and prompted open dialogue between participants surrounding data authenticity and transparency. This indicates potential for future design work to explore how both synchronous and asynchronous experiences and interaction could be designed with combined social data archives. For example, with Queue Player, having an option to toggle between individual (asynchronous) and social (synchronous) listening modes could have provided a sense of familiarity and control that could potentially be scaffolded to reduce initial tensions while still expanding and sustaining experiences of anticipation with the shared archive.

Julian's reflections on not recognizing his data at times was likely due to navigating the temporal density of approximately 10 years' worth of his listening history data (**see section 4.2.2**). However, at the beginning of the study, participants were also unaware that they could request their data from Spotify. This highlights a significant gap between their daily use of the platform and the way in which Spotify tracks and resurfaces their data. While Spotify allows users to interact with their listening history data to in highly constrained ways through minor features like Wrapped, Repeat Rewind, and AI DJ recommendations, their platform retains most control over how this data is used by and presented to end users [30]. This 'curated' form of resurfacing listening history data conveys a vastly incomplete picture of users' data, which may have contributed to participants' disorientation at the beginning of the study.

Queue Player offers insights into how these tensions with data recognition can be alleviated. By providing a tangible device for participants to 'have' their comprehensive Spotify listening histories (excluding repeat song instances and songs unavailable in the Spotify Canada market), this encouraged them to reflect on their data more critically and extensively. Furthermore, the co-listening aspect of Queue Player allowed them to consider their data in relation to their loved ones' data, 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 the burden of choice [37, 39], while fostering discussions about future listening habits.

Queue Player's design also highlighted the importance of data autonomy. **Florence's** evolution from a cautious listener to someone more self-aware and reflective of her listening habits (**see section 4.1**) illustrates the benefits of having data readily available and materially present in people's lives. Participants' increased awareness of their listening history data suggests that giving users more control and transparency over their data can lead to deeper reflections and more meaningful interactions. This aligns with prior research at the intersection of personal data and slow technology, which emphasizes the value of intervening technologies that can 'break data free' from their restrictive platforms in the service of encouraging deeper situated experiences of reflection and mindfulness over longer time periods [7, 8, 52, 54, 55, 73].

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 developed a more nuanced understanding of their musical tastes and the social dynamics that shape them. With this familiarity growing over time, participants also established a sense of intimacy through "knowing more of [each other] through [their] music tastes" (**Florence, section 4.3.1**). Inter-relating 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, which we manifested in the requirement to play songs in full, ensured that participants were able to experience each song in its entirety, allowing for deep reflection and understanding of the music and its significance to others. This complete immersion could lead participants to more profound conversations and shared experiences in future interactions, as they had the time and space to fully engage with the content and each other's perspectives. This is also seen in **Kassandra's** reflection on wondering about the significance of George's music and placing herself into his shoes (**see section 4.3.1**).

With implicit slowness, which was integrated through tap tempo, participants were able to adjust the pace at which they explored the archive. During listening sessions, I observed how tap tempo also instilled a sense of shared agency and enabled

them to bond and collaborate with each other to get the queue to a place where they could all enjoy the music being played.

By integrating implicit and explicit slowness, participants in our study were able to develop deeper understandings of each other and build more empathy and intimacy with each other. This serves as a novel example for how interrelating implicit and explicit slowness can lead to opportunities to support intimacy and social bonding in future research and design work in this space.

5.2. Navigating Personal History Data with Different Temporal Modalities

We chose to use tempo as an input interaction and method for navigating the song archive because of several qualities it posed. First, it was an underutilized and novel case of temporality that was already bound to each song in the database. While prior work in HCI leverages timestamp metadata to reveal insights for re-encountering personal histories (e.g., [6, 8, 47]), 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. In contrast, tempo 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, and this approach created opportunities for anticipation and serendipity, as participants navigated the archive in unpredictable ways.

Gregory's reflection on Queue Player allowing him and the other participants to establish an understanding of each other and get snapshots of their listening habits at different tempos (**see section 4.3.2**) demonstrates how tempo enabled the 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 deeper understanding of each other in varied contexts. Furthermore, organizing songs by valence and danceability metrics allowed for broader explorations of each participant at a specific tempo. While a tempo could be revisited numerous times, the chance to explore different aspects of it for each participant provided a more holistic picture of

themselves and their listening habits. This approach ensured that the archive remained rich and multifaceted, offering participants new insights and reflections with each interaction.

Second, organizing the database by tempo separated songs from chronological connotations specific to each participant, and offered more detailed insights into how the temporal quality of songs can influence everyday life experiences and activities. For instance, the tempo of songs played a part in **Gregory's** personal experiences with tinnitus, while it also influenced the types of activities **Florence** engaged in while using her Queue Player. **Gregory's** experience of considering what other participants could have been doing at certain tempos also indicates the social implications of tempo on curious listening experiences. These accounts all exhibit *pre-interaction*, where subtle and sustained feelings of anticipation with tempo prompted participants to engage with their shared data beyond mere listening. This also shows promise for future research to explore how integrating different or alternative temporal modalities can enhance the depth and quality of user interactions with personal and shared data and evoke agency through enabling experiences that are unique to each user.

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 expand on tempo as an input interact and combine it 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. Integrating different temporal dimensions, such as day, month, year, and even seasons, could enhance the contextualization of listening histories, leading to richer and 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 weren’t attributed to them in the queue despite listening to them previously. This highlights how personal history data can promote reminiscence of one’s listening history and personal history, while also revealing broader implications for managing personal histories.

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 such as the radio, YouTube, iTunes, social media, and even analog media like CDs and vinyl records. For example, during our final group interview, **Gregory** noted that he frequently uses platforms like Discord and YouTube music alongside Spotify as a part of his daily listening. 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 is an excellent example of an aggregator that already does this, but it is still incapable of portraying a fully comprehensive archive to its users. This insight suggests that designers, researchers, and end users should acknowledge the impossibility of a perfect, authentic, and objective personal data history archive. By doing so, they can better engage with experiences that mobilize individually combined personal data in shared data experiences and set realistic expectations of and for their data.

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'. There are also similar implications for other types of personal data, such as digital photographs or audio recordings, that become diffracted across different media platforms over time.

Slow technology, which emphasizes designing for reflection and long-term engagement, can further enhance the value of more comprehensive histories. By deliberately integrating features that encourage users to reflect on their listening patterns over time and across platforms, researchers and designers can create richer, more meaningful listening experiences.

Importantly, **Kassandra's and Julian's** reflections on how external factors like Spotify recommendations and sharing their accounts with others introduced unfamiliar songs, or 'grey spots' into their histories. This demonstrates the fragility of data histories, and the unlikelihood of maintaining completely 'pure' or 'complete' datasets. However, experiencing their data in this way gave participants space to explore and contextualize their data across time. It also enabled reflection on different life experiences in a manner that traditional music streaming could not have afforded.

Similarly, **Gregory's** reflection on music profiling points to the individual and social expectations of each person's data in a social group, and the assumption that the data is completely curated by each individual alone. Another assumption is that data history is a comprehensive reflection of its owner. However, black and grey spots in data histories can present very reduced representations of individuals—as the participants experienced throughout the study—while still retaining much of the data that is procured by them and over time. This suggests an opportunity for future work that can create a balance between surfacing more comprehensive data histories and contextualization of 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 research and design practice for creating both individual and collective experiences with data reminiscence.

5.4. Sustaining Social Connections through Presence and Tangibility

Our study revealed that participants' appreciation for how Queue Player facilitated social presence and awareness of each other. **Kassandra, George, and Florence**, all shared that Queue Player's indicator lights prompted them to interact with their device and also engage with others who were co-listening. **Julian's** reflection on how the indicator lights helped him to infer things about participants like their schedules and routines, further demonstrates the potential integrating features for subtle social presence into technologies for sustaining relationships during synchronous distributed experiences.

The indicator lights not only triggered interactions but also created new pathways for participants to better understand each other's listening habits and the dynamics of the group as a whole. Future research supporting longer-term use of similar systems could expand on this by actively encouraging touchpoints between users during peak activity times. While Queue Player facilitated open-ended engagement, new systems could potentially utilize machine learning to track user engagement over time and subtly prompt certain participants to engage with their devices together, without demanding attention or interaction. This could create more opportunities for social bonding, and generate more interconnections within the group and between different users. For instance, **Kassandra** mentioned that she usually only saw **Julian** listening at the same time as she did. Implementing an additional indicator for them to connect during these times could have created bonding experiences and more reflections specific to their connection, while also introducing another layer of social translucence. In a case like this, users would be able to have a more dialed in awareness of each other and may be more inclined to co-listen once specific users are present

The tangibility of Queue Player builds on one of Antle and Wise's key guidelines for designing tangible interfaces: that the spatial properties of tangible interfaces should be mobilized to encourage individual engagement, better awareness of what others are doing, and shared attention to the artifact [1]. Queue Player achieved this through the queue and indicator lights, which both enabled anticipation through *pre-interaction*. While participants had their Queue Players off, they were still able to see when other users were co-listening via the indicator lights. Similarly, while multiple Queue Players

were active, attending to a synchronized queue allowed participants to share their experiences in real-time, enhancing the sense of co-presence and collective engagement. The circular form factor of the Queue Players also facilitated engagement as participants could see what was happening from any angle in their living spaces. This further allowed participants to connect with each other without disrupting their routines. **Kassandra** and **Julian** explicitly showed examples of this during their listening sessions, as I observed them engaging in other tasks (cooking and cleaning) while their Queue Player played music in the background.

These findings suggest opportunities for future work to further investigate how form can significantly influence the situated ways in which users interact with each other when using a system geared towards synchronous distributed experiences. It also suggests the need to explore how features could be implemented to invite experiences surrounding social translucence that richly indicate co-presence during passive and active engagement can help to sustain connections and encourage intimacy and closeness within a social group.

Chapter 6.

Limitations and Future Work

While the Queue Player field study generated rich insights for future work in research and design practice, several limitations highlight opportunities for future work in this research space.

One limitation of the study was its duration. We had initially intended for the study to be conducted over 3 months to give participants time to fully interpret and engage with their Queue Players. However, listening sessions and the final group interview required coordinating 4 participants' schedules and availability to effectively engage in co-listening experiences, and this proved to be a challenge. Furthermore, design events that occurred throughout the RtD process also delayed the start date of the study, which ultimately led us to conducting a 6-week 'field trial'. While participants could have potentially benefitted from a longer study, the field trial still allowed us to investigate the potential Queue Player has for synchronous distributed co-listening. It also allowed us to gauge participants' experiences and perceptions without over-committing to a longer field study, and still uncover valuable insights into the dynamics of co-listening via a tangible music player for future work and potentially a longer-term field study. Promisingly, all of the participants expressed interest in having their Queue Players for a longer period of time. During the final group interview, **Julian** shared that more time would have allowed him to develop a better sensibility towards using tap tempo, enabling a deeper exploration of the archive and a broader understanding of the other participants. Other participants also echoed this sentiment, which suggests opportunities for future research with Queue Player and/or similar systems.

Another limitation was the study's demographic homogeneity. Participants for the study were all close in age (at most 10 years apart), and all lived in Metro Vancouver. This demographic was ideal for closely observing the social dynamics within the group, and the shared geographical location facilitated the deep hanging out approach we adopted for the study. However, there is room to examine how co-listening can be used to foster and sustain social connections and reflections among more diverse social groups with pre-existing relationships. For example, how might a study like this play out

with intergenerational families or loved ones? What insights could emerge from the different kinds of histories, stories, and intimacies a social group like this might have?

Furthermore, future work could involve deploying the Queue Players to friends or family in different parts of Canada or even around the world. This would help us better understand how such tangible devices can mediate relationships across larger physical distances, cultures, time zones, and varied everyday experiences. Because Junkanoo was such an instrumental influence in Queue Player's design, we originally wanted to recruit participants from the Caribbean Diaspora living away from their home countries. We wanted to explore how Queue Player could facilitate co-listening experiences and foster connections to home, given the Caribbean people's deep cultural immersion in music, particularly in rhythm and tempo. This approach would have also allowed us to examine how integrating cultural practices into a design can mediate feelings of cultural displacement and potentially help immigrants and migrants integrate into their new environments while maintaining connections to home. However, finding participants in this demographic who knew me and met the other study criteria proved to be challenging in Metro Vancouver. Nonetheless, this remains an interesting and important research space worth pursuing in future work.

Finally, we only utilized a limited dataset of the participants' data for the study. Since their extended streaming histories were requested from Spotify prior to the study, there was a no data beyond the point of when participants made their requests. While the amount of songs in the database was more than what participants could explore over the course of 6 weeks, there is room for future research in this space to explore the potential of a more dynamic database for co-listening. The data we used was truly from the participants' pasts, but integrating more recent entries from their listening histories into the database could reveal more insights and probe different reflections around daily listening habits and present experiences.

Chapter 7.

Conclusion

Through the design, implementation, and deployment of 4 *Queue Player* research products, my thesis research makes two contributions to HCI and design communities.

First, it introduces a set of novel music players, *Queue Players*, in which tempo is used as a temporal modality for interaction. This makes listening history metadata materially presented to its users so that they can interact with it directly, and also provides insights into direct access to one's listening history through a tangible music player can support open-ended, synchronous distributed co-listening experiences. Through engaging in a Queue Player field study with four friends living apart in Metro Vancouver, I was able to observe their experiences and gauge their reactions towards living with a device that allows them to persistently revisit and explore their music listening histories over a long period of time. I was also able to see how they interpreted their data, their friends' data, and their data as a whole through the experiences they had while using their Queue Players. Findings showed that Queue Player was able to uncover new individual perceptions towards personal data, and through supporting co-listening, enabled participants to form new connections towards their personal and shared song listening histories. Participants exhibited feelings of anticipation, curiosity, and serendipity as their explored their listening histories in new and unexpected ways.

Second, it offers a design research case that further expands strategies for how slow technology can fit into everyday objects in people's lives, so that they can intentionally interact and evolve with these objects over long periods of time. Queue Player's design was informed by several qualities of slow technology which allowed participants to have a range of experiences while listening alone and while co-listening. It allowed participants to reflect on their data more comprehensively and consider and discover new aspects of each other's lived through deep listening and interpretation. They experienced moments of social bonding, trust, and intimacy, through being present and through intentional interactions (or non-interactions) with their Queue Players.

These insights serve as a design case for using slow technology as a lens for facilitating reflection and social connection in synchronous distributed co-experiences. Through the design and deployment of Queue Players, I also see an opportunity for future research and design work to explore alternative ways of using metadata other temporal modalities as materials for re-engaging with and deeply exploring personal data archives and combined data archives over long periods of time.

References

[1] Alissa N. Antle and Alyssa F. Wise. 2013. Getting Down to Details: Using Theories of Cognition and Learning to Inform Tangible User Interface Design. *Interacting with Computers* 25, 1 (January 2013), 1–20. https://doi.org/10.1093/iwc/iws007

[2] Arianna Bassoli, Julian Moore, and Stefan Agamanolis. 2006. Tuna: Socialising Music Sharing on the Move. In *Consuming Music Together*, Kenton O'Hara and Barry Brown (eds.). Springer-Verlag, Berlin/Heidelberg, 151–172. https://doi.org/10.1007/1-4020-4097-0_8

[3] Dominikus Baur, Jennifer Büttgen, and Andreas Butz. 2012. Listening factors: a large-scale principal components analysis of long-term music listening histories. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, May 05, 2012. ACM, Austin Texas USA, 1273–1276. https://doi.org/10.1145/2207676.2208581

[4] Daniel Boland and Roderick Murray-Smith. 2013. Finding my beat: personalised rhythmic filtering for mobile music interaction. In *Proceedings of the 15th international conference on Human-computer interaction with mobile devices and services*, August 27, 2013. ACM, Munich Germany, 21–30. https://doi.org/10.1145/2493190.2493220

[5] Amy Yo Sue Chen and William Odom. 2021. Crafting temporality in design: Introducing a designer-researcher approach through the creation of Chronoscope. In *The Routledge International Handbook of Practice-Based Research*. Routledge, 368–380.

[6] Amy Yo Sue Chen, William Odom, Sol Kang, and Carman Neustaedter. 2023. PhotoClock: Reliving Memories in Digital Photos as the Clock Ticks in the Present Moment. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, July 10, 2023. ACM, Pittsburgh PA USA, 1015–1031. https://doi.org/10.1145/3563657.3596020

[7] Amy Yo Sue Chen, William Odom, Carman Neustaedter, Ce Zhong, and Henry Lin. 2023. Exploring Memory-Oriented Interactions with Digital Photos In and Across Time: A Field Study of Chronoscope. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, April 19, 2023. ACM, Hamburg Germany, 1–20. https://doi.org/10.1145/3544548.3581012

[8] Amy Yo Sue Chen, William Odom, Ce Zhong, Henry Lin, and Tal Amram. 2019. Chronoscope: Designing Temporally Diverse Interactions with Personal Digital Photo Collections. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, June 18, 2019. ACM, San Diego CA USA, 799–812. https://doi.org/10.1145/3322276.3322301

[9] Nabila Chowdhury, Celine Latulipe, and James E. Young. 2021. Listening Together while Apart: Intergenerational Music Listening. In *Companion Publication of the 2021 Conference on Computer Supported Cooperative Work and Social Computing*, October 23, 2021. ACM, Virtual Event USA, 36–39. https://doi.org/10.1145/3462204.3481765

[10] Andrew Crossan and Roderick Murray-Smith. 2006. Rhythmic Interaction for Song Filtering on a Mobile Device. In *Haptic and Audio Interaction Design*, David McGookin and Stephen Brewster (eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 45–55. https://doi.org/10.1007/11821731_5

[11] Nick Crossley. 2020. 2 Music as social interaction: Embedded, embodied and multivalent. In *Connecting sounds*. Manchester University Press, 9–39. https://doi.org/10.7765/9781526126023.00006
[12] Nick Crossley. 2020. 7 Practical interactions: Use, taste, identity. In *Connecting sounds*. Manchester University Press, 127–147. https://doi.org/10.7765/9781526126023.00011
[13] Audrey Desjardins and Cayla Key. 2020. Parallels, Tangents, and Loops: Reflections on the "Through" Part of RtD. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. Association for Computing Machinery, New York, NY, USA, 2133–2147. Retrieved April 27, 2022 from http://doi.org/10.1145/3357236.3395586
[14] Audrey Desjardins, Jena McWhirter, Justin Petelka, Chandler Simon, Yuna Shin, Ruby K Peven, and Philbert Widjaja. 2023. On the Making of Alternative Data Encounters: The Odd Interpreters. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, April 19, 2023. ACM, Hamburg Germany, 1–20. https://doi.org/10.1145/3544548.3581323
[15] Ricardo Dias, Manuel J. Fonseca, and Daniel Gonçalves. 2012. Music listening history explorer: an alternative approach for browsing music listening history habits. In *Proceedings of the 2012 ACM international conference on Intelligent User Interfaces*, February 14, 2012. ACM, Lisbon Portugal, 261–264. https://doi.org/10.1145/2166966.2167013
[16] Chris Elsden, Mark Selby, Abigail Durrant, and David Kirk. 2016. Fitter, Happier, More Productive: What to Ask of a Data-driven Life. *interactions* 23, 5 (August 2016), 45–45. https://doi.org/10.1145/2975388
[17] Thomas Erickson, Christine Halverson, Wendy A. Kellogg, Mark Laff, and Tracee Wolf. 2002. Social translucence: designing social infrastructures that make collective activity visible. *Commun. ACM* 45, 4 (April 2002), 40–44. https://doi.org/10.1145/505248.505270
[18] Thomas Erickson and Wendy A. Kellogg. 2000. Social translucence: an approach to designing systems that support social processes. *ACM Trans. Comput.-Hum. Interact.* 7, 1 (March 2000), 59–83. https://doi.org/10.1145/344949.345004
[19] Rowanne Fleck and Daniel Harrison. Shared PI: Sharing Personal Data to Support Reflection and Behaviour Change.
[20] William Gaver. 2012. What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, May 05, 2012. ACM, Austin Texas USA, 937–946. https://doi.org/10.1145/2207676.2208538
[21] Barney G. Glaser, Anselm L. Strauss, and Anselm L. Strauss. 2017. *Discovery of Grounded Theory : Strategies for Qualitative Research*. Routledge. https://doi.org/10.4324/9780203793206
[22] Lisa Graham, Anthony Tang, and Carman Neustaedter. 2016. Help Me Help You: Shared Reflection for Personal Data. In *Proceedings of the 19th International Conference on Supporting Group Work*, November 13, 2016. ACM, Sanibel Island Florida USA, 99–109. https://doi.org/10.1145/2957276.2957293
[23] Anja N Hagen and Marika Lüders. 2017. Social streaming? Navigating music as personal and social. *Convergence* 23, 6 (December 2017), 643–659. https://doi.org/10.1177/1354856516673298
[24] Lars Hallnäs and Johan Redström. 2001. Slow Technology – Designing for Reflection. *Personal Ubiquitous Comput.* 5, 3 (January 2001), 201–212. https://doi.org/10.1007/PL00000019

[25] David J. Hargreaves and Adrian C. North. 1999. The Functions of Music in Everyday Life: Redefining the Social in Music Psychology. *Psychology of Music* 27, 1 (April 1999), 71–83. https://doi.org/10.1177/0305735699271007
[26] Marc Hassenzahl, Stephanie Heidecker, Kai Eckoldt, Sarah Diefenbach, and Uwe Hillmann. 2012. All You Need is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Trans. Comput.-Hum. Interact.* 19, 4 (December 2012), 1–19. https://doi.org/10.1145/2395131.2395137
[27] Dan Hawkins, Jason Procyk, and Carman Neustaedter. 2014. Postulater: slowing the pace of media sharing. In *Proceedings of the 2014 companion publication on Designing interactive systems - DIS Companion '14*, 2014. ACM Press, Vancouver, BC, Canada, 89–92. https://doi.org/10.1145/2598784.2602790
[28] Yasamin Heshmat, Carman Neustaedter, Kyle McCaffrey, William Odom, Ron Wakkary, and Zikun Yang. 2020. FamilyStories: Asynchronous Audio Storytelling for Family Members Across Time Zones. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, April 21, 2020. ACM, Honolulu HI USA, 1–14. https://doi.org/10.1145/3313831.3376486
[29] David Hesmondhalgh. 2008. Towards a critical understanding of music, emotion and self-identity. *Consumption Markets & Culture* 11, 4 (December 2008), 329–343. https://doi.org/10.1080/10253860802391334
[30] Shane Homan (Ed.). 2022. *The Bloomsbury Handbook of Popular Music Policy* (1st ed.). Bloomsbury Publishing Inc. https://doi.org/10.5040/9781501345357
[31] Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B. Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, Nicolas Roussel, and Björn Eiderbäck. 2003. Technology Probes: Inspiring Design for and with Families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (*CHI '03*), 2003. ACM, New York, NY, USA, 17–24. https://doi.org/10.1145/642611.642616
[32] Mizuko Ito, Sonja Baumer, Matteo Bittanti, Danah Boyd, Rachel Cody, Becky Herr Stephenson, Heather A. Horst, Patricia G. Lange, Dilan Mahendran, Katynka Z. Martínez, C. J. Pascoe, Dan Perkel, Laura Robinson, Christo Sims, and Lisa Tripp. 2010. *Hanging out, messing around, and geeking out: kids living and learning with new media*. the MIT press, Cambridge (Mass.).
[33] Sofia Johansson, Ann Werner, Patrik Åker, and Gregory Goldenzwaig. 2018. *Streaming music: practices, media, cultures*. Routledge, an imprint of the Taylor & Francis Group, Abingdon, Oxon ; New York, NY.
[34] Kyung Jin Kim, Sangsu Jang, Bomin Kim, Hyosun Kwon, and Young-Woo Park. 2019. muRedder: Shredding Speaker for Ephemeral Musical Experience. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, June 18, 2019. ACM, San Diego CA USA, 127–134. https://doi.org/10.1145/3322276.3322362
[35] David S. Kirk, Abigail Durrant, Gavin Wood, Tuck Wah Leong, and Peter Wright. 2016. Understanding the Sociality of Experience in Mobile Music Listening with Pocketsong. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, June 04, 2016. ACM, Brisbane QLD Australia, 50–61. https://doi.org/10.1145/2901790.2901874
[36] Timo A. Kosonen and Antti J. Eronen. 2006. Rhythm metadata enabled intra-track navigation and content modification in a music player. In *Proceedings of the 5th international conference on Mobile and ubiquitous multimedia*, December 04, 2006. ACM, Stanford California USA, 1. https://doi.org/10.1145/1186655.1186656

[37] Amanda E. Krause, Adrian C. North, and Lauren Y. Hewitt. 2015. Music-listening in everyday life: Devices and choice. *Psychology of Music* 43, 2 (March 2015), 155–170. https://doi.org/10.1177/0305735613496860

[38] Eva Lenz, Sarah Diefenbach, Marc Hassenzahl, and Sébastien Lienhard. 2012. *Mo.* shared music, shared moment. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction Making Sense Through Design - NordiCHI '12*, 2012. ACM Press, Copenhagen, Denmark, 736. https://doi.org/10.1145/2399016.2399129

[39] Tuck Leong, Frank Vetere, and Steve Howard. 2008. Abdicating choice: the rewards of letting go. *Digital Creativity* 19, 4 (December 2008), 233–243. https://doi.org/10.1080/14626260802550777

[40] Tuck W. Leong and Peter C. Wright. 2013. Revisiting Social Practices Surrounding Music. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (*CHI '13*), 2013. ACM, New York, NY, USA, 951–960. https://doi.org/10.1145/2470654.2466122

[41] Tuck Wah Leong, Steve Howard, and Frank Vetere. 2008. Choice: Abdicating or exercising. (2008), 10.

[42] Jen-Yu Liu and Yi-Hsuan Yang. 2012. Inferring Personal Traits from Music Listening History. In *Proceedings of the Second International ACM Workshop on Music Information Retrieval with User-centered and Multimodal Strategies* (*MIRUM '12*), 2012. ACM, New York, NY, USA, 31–36. https://doi.org/10.1145/2390848.2390856

[43] Danielle Lottridge, Nicolas Masson, and Wendy Mackay. 2009. Sharing empty moments: design for remote couples. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, April 04, 2009. ACM, Boston MA USA, 2329–2338. https://doi.org/10.1145/1518701.1519058

[44] Matthew B. Miles and A. Michael Huberman. 1985. *Qualitative data analysis*. Sage Newbury Park,, CA. Retrieved January 11, 2017 from http://researchtalk.com/wp-content/uploads/2014/01/Miles-Huberman-Saldana-Drawing-and-Verifying-Conclusions.pdf

[45] William Odom. 2021. Tensions and Techniques in Investigating Longitudinal Experiences with Slow Technology Research Products. In *Advances in Longitudinal HCI Research*, Evangelos Karapanos, Jens Gerken, Jesper Kjeldskov and Mikael B. Skov (eds.). Springer International Publishing, Cham, 153–176. https://doi.org/10.1007/978-3-030-67322-2_8

[46] William Odom, Richard Banks, Abigail Durrant, David Kirk, and James Pierce. 2012. Slow technology: critical reflection and future directions. In *Proceedings of the Designing Interactive Systems Conference*, June 11, 2012. ACM, Newcastle Upon Tyne United Kingdom, 816–817. https://doi.org/10.1145/2317956.2318088

[47] William Odom and Tijs Duel. 2018. On the Design of OLO Radio: Investigating Metadata as a Design Material. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, April 19, 2018. ACM, Montreal QC Canada, 1–9. https://doi.org/10.1145/3173574.3173678

[48] William Odom, Mark Selby, Abigail Sellen, David Kirk, Richard Banks, and Tim Regan. 2012. Photobox: on the design of a slow technology. In *Proceedings of the Designing Interactive Systems Conference*, June 11, 2012. ACM, Newcastle Upon Tyne United Kingdom, 665–668. https://doi.org/10.1145/2317956.2318055

[49] William Odom, Erik Stolterman, and Amy Yo Sue Chen. 2022. Extending a Theory of Slow Technology for Design through Artifact Analysis. *Human–Computer Interaction* 37, 2 (March 2022), 150–179. https://doi.org/10.1080/07370024.2021.1913416

[50] William T. Odom, Abigail J. Sellen, Richard Banks, David S. Kirk, Tim Regan, Mark Selby, Jodi L. Forlizzi, and John Zimmerman. 2014. Designing for Slowness, Anticipation and Re-visitation: A Long Term Field Study of the Photobox. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (*CHI '14*), 2014. ACM, New York, NY, USA, 1961–1970. https://doi.org/10.1145/2556288.2557178

[51] William Odom, Ron Wakkary, Ishac Bertran, Matthew Harkness, Garnet Hertz, Jeroen Hol, Henry Lin, Bram Naus, Perry Tan, and Pepijn Verburg. 2018. Attending to Slowness and Temporality with Olly and Slow Game: A Design Inquiry Into Supporting Longer-Term Relations with Everyday Computational Objects. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (*CHI '18*), 2018. ACM, New York, NY, USA, 77:1-77:13. https://doi.org/10.1145/3173574.3173651

[52] William Odom, Ron Wakkary, Jeroen Hol, Bram Naus, Pepijn Verburg, Tal Amram, and Amy Yo Sue Chen. 2019. Investigating Slowness as a Frame to Design Longer-Term Experiences with Personal Data: A Field Study of Olly. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, May 02, 2019. ACM, Glasgow Scotland Uk, 1–16. https://doi.org/10.1145/3290605.3300264

[53] William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. 2016. From Research Prototype to Research Product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (*CHI '16*), 2016. ACM, New York, NY, USA, 2549–2561. https://doi.org/10.1145/2858036.2858447

[54] William Odom, Jordan White, Samuel Barnett, Nico Brand, Henry Lin, Minyoung Yoo, and Tal Amram. 2024. Capra: Making Use of Multiple Perspectives for Capturing, Noticing and Revisiting Hiking Experiences Over Time. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, May 11, 2024. ACM, Honolulu HI USA, 1–27. https://doi.org/10.1145/3613904.3642284

[55] William Odom, MinYoung Yoo, Henry Lin, Tijs Duel, Tal Amram, and Amy Yo Sue Chen. 2020. Exploring the Reflective Potentialities of Personal Data with Different Temporal Modalities: A Field Study of Olo Radio. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, July 03, 2020. ACM, Eindhoven Netherlands, 283–295. https://doi.org/10.1145/3357236.3395438

[56] Kenton O'Hara and Barry Brown. 2006. *Consuming Music Together: Social and Collaborative Aspects of Music Consumption Technologies*. Springer Netherlands, Dordrecht.

[57] Doenja Oogjes and Audrey Desjardins. 2024. A temporal vocabulary of Design Events for Research through Design. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, May 11, 2024. ACM, Honolulu HI USA, 1–12. https://doi.org/10.1145/3613904.3642560

[58] Doenja Oogjes and Ron Wakkary. 2022. Weaving Stories: Toward Repertoires for Designing Things. In *CHI Conference on Human Factors in Computing Systems*, April 27, 2022. ACM, New Orleans LA USA, 1–21. https://doi.org/10.1145/3491102.3501901

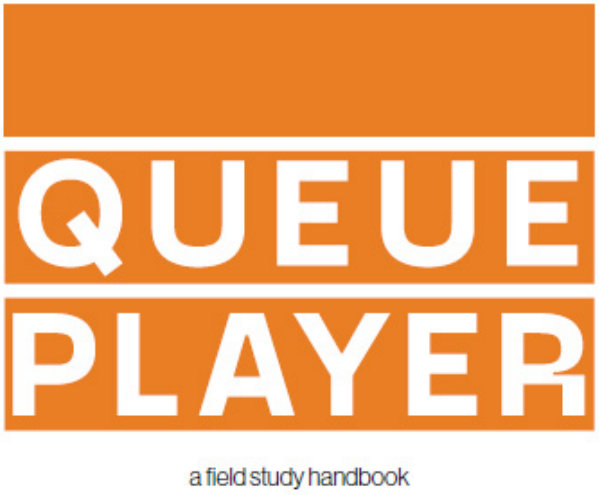
[59] So Yeon Park and Blair Kaneshiro. 2021. Social Music Curation That Works: Insights from Successful Collaborative Playlists. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW1 (April 2021), 1–27. https://doi.org/10.1145/3449191

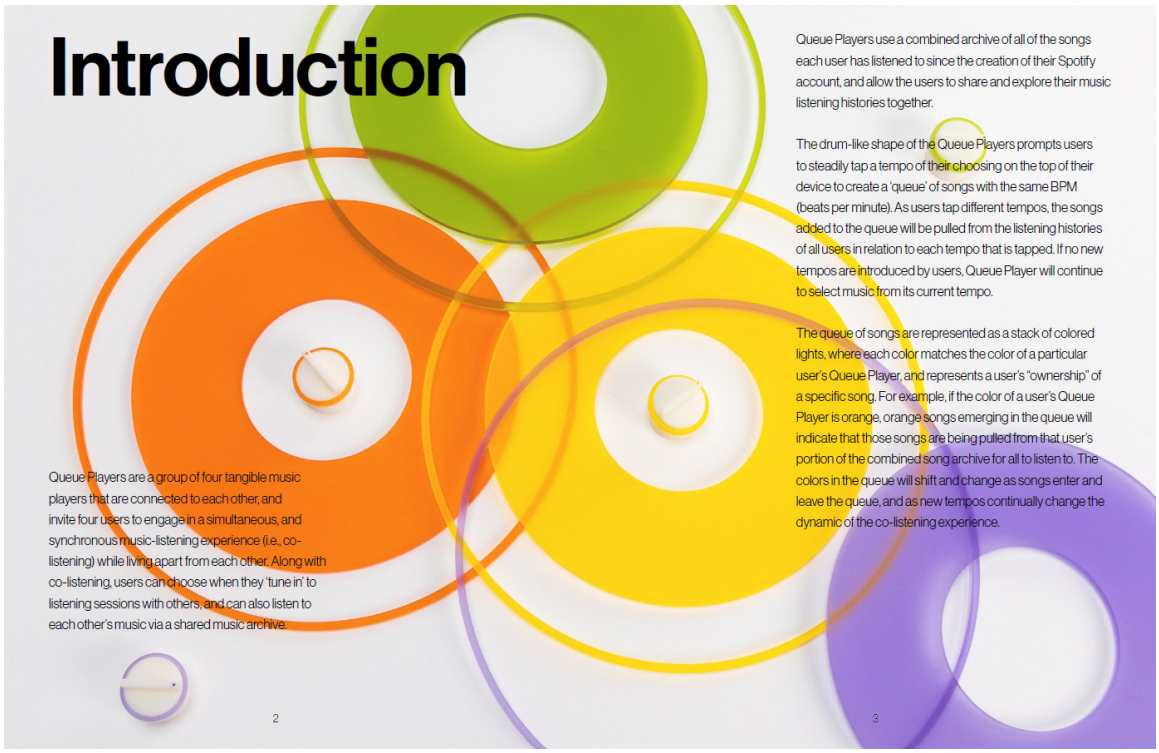
[60] Larissa Pschetz and Richard Banks. 2013. Long living chair. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, April 27, 2013. ACM, Paris France, 2983–2986. https://doi.org/10.1145/2468356.2479590

[61] Tony Salvador, Genevieve Bell, and Ken Anderson. 1999. Design Ethnography. *Design Management Journal (Former Series)* 10, 4 (October 1999), 35–41. https://doi.org/10.1111/j.1948-7169.1999.tb00274.x
[62] Robert P. Snow. 1987. Interaction with mass media: The importance of rhythm and tempo. *Communication Quarterly* 35, 3 (June 1987), 225–237. https://doi.org/10.1080/01463378709369686
[63] Louis Spinelli, Josephine Lau, Liz Pritchard, and Jin Ha Lee. 2018. INFLUENCES ON THE SOCIAL PRACTICES SURROUNDING COMMERCIAL MUSIC SERVICES: A MODEL FOR RICH INTERACTIONS. (2018), 7.
[64] Michael Stewart, Javier Tibau, Deborah Tatar, and Steve Harrison. 2018. Co-designing for Co-listening: Conceptualizing Young People's Social and Music-Listening Practices. In *Social Computing and Social Media. User Experience and Behavior*, Gabriele Meiselwitz (ed.). Springer International Publishing, Cham, 355–374. https://doi.org/10.1007/978-3-319-91521-0_26
[65] Rob Strong and Bill Gaver. Feather, Scent, and Shaker: Supporting Simple Intimacy. 2.
[66] Jan Stupacher, Pieter-Jan Maes, Matthias Witte, and Guilherme Wood. 2017. Music strengthens prosocial effects of interpersonal synchronization – If you move in time with the beat. *Journal of Experimental Social Psychology* 72, (September 2017), 39–44. https://doi.org/10.1016/j.jesp.2017.04.007
[67] Jan Stupacher, Guilherme Wood, and Matthias Witte. 2017. Synchrony and sympathy: Social entrainment with music compared to a metronome. *Psychomusicology: Music, Mind, and Brain* 27, 3 (September 2017), 158–166. https://doi.org/10.1037/pmu0000181
[68] Petek Tezcan, Saskia Bakker, and Berry Eggen. 2017. Musico: Personal Playlists through Peripheral and Implicit Interaction. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems*, June 10, 2017. ACM, Edinburgh United Kingdom, 121–126. https://doi.org/10.1145/3064857.3079131
[69] Javier Tibau, Michael Stewart, Steve Harrison, and Deborah Tatar. 2019. FamilySong: Designing to Enable Music for Connection and Culture in Internationally Distributed Families. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, June 18, 2019. ACM, San Diego CA USA, 785–798. https://doi.org/10.1145/3322276.3322279
[70] Grace Turner. 2011. spontaneity and enjoyment always so charac- teristic of Junkanoo. (2011).
[71] Michael James Walsh. 'I'm also slightly conscious of how much I'm listening to something': Music streaming and the transformation of music listening.
[72] Mark Weiser and John Seely Brown. Designing Calm Technology. 5.
[73] Jordan White, William Odom, Nico Brand, and Ce Zhong. 2023. Memory Tracer & Memory Compass: Investigating Personal Location Histories as a Design Material for Everyday Reminiscence. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, April 19, 2023. ACM, Hamburg Germany, 1–19. https://doi.org/10.1145/3544548.3581426
[74] Jordan Wirfs-Brock, Sarah Mennicken, and Jennifer Thom. 2020. Giving Voice to Silent Data: Designing with Personal Music Listening History. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–11. Retrieved February 17, 2022 from https://doi.org/10.1145/3313831.3376493

[75] Peter Wogan. 2004. Deep Hanging Out: Reflections on Fieldwork and Multisited Andean Ethnography. *Identities* 11, 1 (January 2004), 129–139. https://doi.org/10.1080/725289021
[76] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, April 29, 2007. ACM, San Jose California USA, 493–502. https://doi.org/10.1145/1240624.1240704
[77] John Zimmerman, Erik Stolterman, and Jodi Forlizzi. An Analysis and Critique of Research through Design: towards a formalization of a research approach.
[78] 2015. What your heart rate is telling you. *Harvard Health*. Retrieved July 25, 2024 from https://www.health.harvard.edu/heart-health/what-your-heart-rate-is-telling-you
[79] 2019. Music Devices Through Time. *Blackpool Grand Theatre*. Retrieved August 15, 2024 from https://www.blackpoolgrand.co.uk/music-devices-through-time
[80] The music lives on. *Apple Newsroom (Canada)*. Retrieved August 15, 2024 from https://www.apple.com/ca/newsroom/2022/05/the-music-lives-on/
[81] Spotify — About Spotify. *Spotify*. Retrieved August 15, 2024 from https://newsroom.spotify.com/company-info/
[82] Metronome | Definition, Tempo, & Beat | Britannica. Retrieved July 25, 2024 from https://www.britannica.com/art/metronome
[83] Metronome. Retrieved July 25, 2024 from https://www.sfu.ca/sonic-studio-webdav/handbook/Metronome.html
[84] Target Heart Rates Chart. *www.heart.org*. Retrieved July 25, 2024 from https://www.heart.org/en/healthy-living/fitness/fitness-basics/target-heart-rates
[85] Deep Hanging Out | Clifford Geertz | The New York Review of Books. Retrieved July 25, 2024 from https://www.nybooks.com/articles/1998/10/22/deep-hanging-out/

Appendix A. Queue Player Field Study Guide





Design Qualities

Tap Tempo

Rhythm and tempo are a significant aspect of Caribbean culture, and act as an ever-changing pulse that drives various activities in daily life. Queue Player's design was particularly inspired by the Bahamian music festival Junkanoo, which is centered around the steady beat of goat skin drums. As drummers beat their drums with different tempos and rhythms, festival spectators experience a feeling of togetherness, and all move along to the beat and with each other.

As a Bahamian living outside of my country, I wanted to integrate this aspect of my culture into the design for Queue Player by using tap tempo as a new approach to song selection, and beats per minute as a way to organize and explore a vast collection of shared music. In short, our goal is for Queue Player to extend users' existing music listening practices and explore how tempo and rhythm might shape how users experience their music listening histories, and if this new type of music player could foster deeper feelings of connection with co-listeners and to their music.

Fig 1-3 2022 Boxing Day Junkanoo Festival, Nassau, Bahamas

With tap tempo as the only form of interaction for controlling what music is played, we seek to encourage more curiosity, playfulness, and openness with music sharing in a social context. We also want to highlight the fact that while users' music tastes may vary, their songs will still have an aspect of harmony among them through their shared tempos.

Slowness

As songs slowly move up the queue, users may find opportunities to reflect on songs from their past and the emotions and memories associated with them. By slowing down the rate at which songs are played, and limiting what is known about each song to only tempo and who has listened to it in the past, we hope to give users a chance to experience each other's songs through listening and interpretation, as well as the opportunity to broaden their musical tastes.

This design quality of 'slowness' will also give users the chance to reflect on their music in a social context, discover possible connections they have with the other users through shared songs, and potentially reveal insights from their individual reflections, as well as encourage more curiosity, playfulness, and openness with music sharing in a social context. We also want to highlight the fact that while users' music tastes may vary, their songs will still have an aspect of harmony among them through their shared tempos.

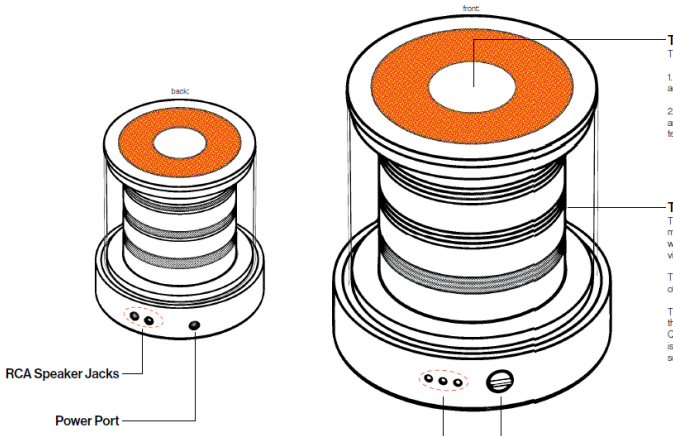
Social Awareness

Since Queue Players are distributed between different households, we wanted to provide a way for users to be subtly aware of the presence of their friends and fellow users. Small indicator LEDs that match each user's Queue Player color will turn on and off to communicate when someone is co-listening, even if their Queue Player is 'OFF'. This will provide a sense of continual social awareness of others and, perhaps, trigger curiosity to engage in collective interaction while not requiring interaction or interrupting any users' routines.

Having an awareness of other users may also encourage users to consider the intentions of when, how, and why others interact with their Queue Player.

How To Use Your Queue Player

Your Queue Player



Tapping Interface
The Tapping Interface has two functions:

1. Tapping a steady tempo on the surface will allow you to select a new tempo to be added to the Queue.

2. 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.

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 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 subsequet 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.

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.

Volume/ Power Knob
The volume and power knob will control the volume at which music is played when the knob is turned towards the right, and the power will be 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 timestamp that all users are at.

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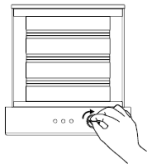
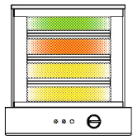
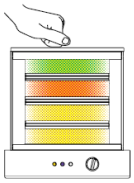
① 

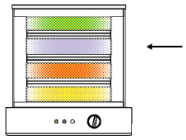
Turn the knob towards the right to turn the power on and increase your Queue Player's volume.

② 

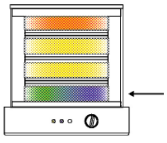
Once your Queue Player turns on, the queue will be populated with songs t hat match the current tempo. The color of each section in the queue represents a specific user, and that they have listened to a specific song in past. The currently playing song is represented by the top section of the queue.

③ 

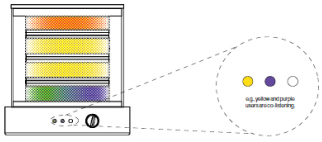
Tap a steady tempo on the top of your Queue Player (the tapping interface) t o change the tempo for songs to be played next.

④ 

The queue will be cleared of all songs except the song in the top section. A song from the person who tapped will enter the queue at the t op-most available section (excluding the first section). This song will match the tempo they tapped, and subsequent songs will also match this tempo. The section of the queue with the n ewly tapped song will also be dimmed until it reaches the first section.



If two or more users have listened to a song in the past, the song will be r epresented by a g radient of the users' colors.



Indicator lights at the base of the Queue Player will display which u sers a re currently l istening to their Queue Players.

How You Can Use Your Queue Player

Try to change the tempo of upcoming songs based on an activity you're currently doing.

What tempos would you select for activities like exercising, cooking, cleaning, reading, socializing, or simply relaxing?

What kinds of activities do you do in your home that pair well with Queue Player?

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sway the group

If the tempo remains unchanged for a while, try to change the overall mood for the group by changing the tempo (e.g., fast to slow, or slow to fast).

Do you notice subtle or significant changes in the mood when you alter the tempo?

Do slight adjustments change the group's overall mood?

As you explore different tempos, try to make slight adjustments too – Queue Player can pick up on very precise changes in tempo.

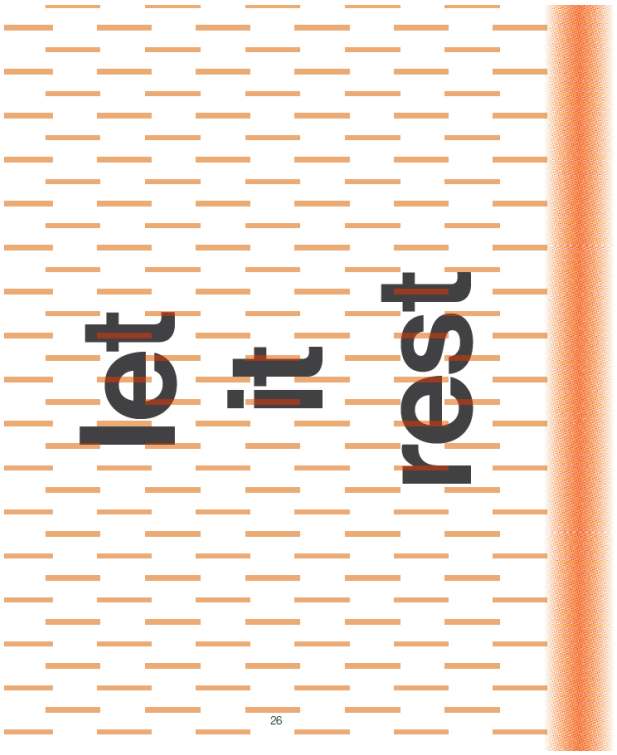
call and response

If you notice a new tempo enter the queue, immediately respond with a different tempo.

What kinds of tempo changes trigger others in the group to queue up songs as well?

Do you experience feelings of surprise or anticipation when you see others have started to introduce new tempo changes into the queue?

How does it feel to 'move' through the collective listening history archive through this more rhythmic form of interaction?



Allow the current tempo to play out for a while without introducing any new tempos.

Does focusing on the tempo of songs and who they originally 'belonged' to affect your music listening experience?

Does the relatively minimal amount of information available about each song change how you think about each song as it plays?

Whenever a shared song comes up in the queue (i.e., a gradient is shown), how does each 'owner' reflect on their past experience with the song?

Once you experience a shared song, feel free to share any feelings and/or anecdotes associated with the song.

Do you notice any shared experiences and connections that you and others have to the song, or any differences between how each person has experienced it?

How do these reflections affect your current feelings toward the song?

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Notes

When observing the queue, do you notice any patterns in the sequence of songs, or any connections between songs that you may not have considered before?

Do you notice any connections between lyrics, mood, genre, or even culture?

Do you notice any considerable differences between songs, or between the types of songs played for certain tempos?

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Appendix B. Initial Interview Questions

Queue Player Initial Interview

1. **Demographics:**
    a. What is your age?
    b. Where is your cultural background?
    c. What is your occupation?
    d. What is your living situation like? (e.g., roommates, type of housing, etc.)

2. **Relationship to music:**
    a. What is your relationship to music?

    b. How often would you say you listen to music with other people, in a more social context? Would you like to socially listen (or co-listen) to music more often if you could?

    c. How does co-listening to music with others change or shape your experience of music listening in general? Is it different from when you listen to music on your own/individually? Why?

    d. Have you noticed any changes in your listening habits or experiences as technology has changed over your life (e.g. from tapes, CDs, mp3s, vinyl, to online streaming now)?

    e. How long have you been listening to music and how long have you had your Spotify account?

3. **Perception of listening history:**
    a. What is your perception of your Spotify listening history data?
        i. Do you care about it? If not, why? If so, why? What do you think your data says about you?

        ii. Before this study, did you ever think about trying to 'get' your data and 'have it' in some form? Explain.

iii. What was your experience like in 'getting' your data from Spotify? Did you look at it? If so, what did you find?
iv. How do you feel about combining your listening history with 3 of your friends'? Do you think there's potential to discover unknown or partially unknown connections between you and your friends?

v. How do you feel/ what do you think about listening back to music from yours and your friends' collective pasts? (Note: clarify that QP isn't meant to replace their existing listening practices of listening to current and new music, but rather to extend what is possible in terms of music listening in both individual and social contexts).

4. Final Questions:

a. Do you have any questions about Queue Player or field study?

Appendix C. Listening Session Questions

Listening Session Interviews (Individual)

General individual questions for listening sessions include (*prioritize highlighted questions*):

- What has your experience with Queue Player been like so far?
    - In general, how did you feel about having a Queue Player in your home?
    - How often did you use it?
    - Can you describe the different times of day you used it and why (e.g., morning, afternoon, night)? Were there specific scenarios where you were more likely to use it?

- What kinds of activities do you do in your home that pair well with Queue Player?

- Have you faced any challenges getting used to how the system works, or the type of interactions it requires? Please explain why or why not.

- Has anyone else in your household used your Queue Player? How have they reacted to it?

- Have you shown the device to other people outside of your household? If so, who?

- Can you reflect on how your relationship with your Queue Player evolved as you used it? Can you also reflect on your use of tap tempo over time?

PERCEPTIONS OF SPOTIFY DATA (PERSONAL AND SOCIAL) & MUSIC LISTENING PRACTICES

- After you've had the Queue Player for a while, has it changed how you perceive or think about your Spotify listening history data?
    - Do you see any new kind of value in 'having it' in this form (as opposed to not having it like how it largely was before the study started)?

    - Would you say you care about it more or less than before the study started?

    - What does *your* Spotify Listening History 'say' about you now that you're able to listen back to it?

    - How does it feel having your own listening history mixed in with 3 other friends?
        - Do you think there's potential to discover unknown or maybe partially known connections among you and your friends?

    - Has it led to any surprising, fun, or unexpected experiences?

- Thus far in the study, how has it felt listening back to music from your and their collective pasts?

- Our goal is to help extend what's possible for your music listening practices – has any experiences with Queue Player changed what you want to listen to in your everyday life (e.g., when you actively use Spotify).

SOCIAL AWARENESS OF OTHERS // SOCIAL TRANSLUCENCE & MUSIC LISTENING

- How has your experience been to live with a device that gives a kind of presence/awareness of others around you?
  - Like being aware when other friends are listening and changing the Queue? And also, being aware of what other music friends have listened to in the past?
  - When you see someone's indicator light turn on or off, does that influence your experience with using your Queue Player?

PERCEPTIONS OF SLOWNESS AND LIMITED CONTROL WHILE LISTENING

Preface the discussion around slowness with this explanation from the Queue Player Booklet → "As songs slowly move up the queue, users may find opportunities to reflect on songs from their past and the emotions and memories associated with them. By slowing down the rate at which songs are played, and limiting what is known about each song to only tempo and who has listened to it in the past, we hope to give users a chance to experience each other's songs through listening and interpretation, as well as the opportunity to broaden their musical tastes. This design quality of 'slowness' will also give users the chance to reflect on their music in a social context, discover possible connections they have with the other users through shared songs, and potentially reveal insights from their individual reflections, as well as encourage more curiosity, playfulness, and openness with music sharing in a social context. We also want to highlight the fact that while users' music tastes may vary, their songs will still have an aspect of harmony among them through their shared tempos."

- After using Queue Player for a while now, what do you think about the slowness in the design?
  - Are there any tensions that you've experienced while using Queue Player and listening to songs play to completion? How has this differed from your experiences with using Spotify where skipping, searching, etc., are allowed?

  - When you *see* songs in the Queue, but you have not yet heard them, do you think about what they might be or what might be played? Like if the vibe of the music would be continual or change? (--> this question gets at Pre-Interaction)

  - What has been your experience with waiting for your song to be played after you've introduced a new tempo to the queue? What emotions do you feel while waiting (e.g., anticipation, curiosity, frustration)?

- How does the relatively minimal amount of information available about songs change how you think about and reflect on each song as it plays, or as it is queued up to be played?

- What feelings emerge when you relinquish control over what songs are played, since you have no control over what part of your listening history songs are pulled from?

PERCEPTIONS OF PATTERNS IN THE QUEUE

- When observing the queue, do you notice any patterns in the sequence of songs?
  - (e.g., one particular user may "dominate" a certain tempo, you and another user may share several songs with the same tempo, you and another user may listen to a lot of the same songs in the same genre, etc.)

  - Do you have any feelings towards changes in the queue? (e.g., if you are anticipating a certain upcoming song, and someone adds a tempo and "erases" that song from the queue, what feelings emerge)? How do you feel about the dynamic/ephemeral nature of the queue?

  - When observing the queue, do you notice any patterns in the sequence of songs, or any connections between songs that you may not have considered before? For example, do you notice any connections between lyrics, mood, genre, or even culture? Do you notice any considerable differences between songs?

PERCEPTIONS OF SHARED SONGS AND COMBINED LISTENING HISTORIES

- Whenever a shared song comes up in the queue (i.e., a gradient is shown), how does each 'owner' reflect on their past experience with the song?
  - Do you notice any shared experiences and connections to a song, or any differences between your experience and someone else's? Have you shared any anecdotes with the other participants?

  - When you see that one of your songs is shared with someone else, does that influence your feelings toward the song?

PERCEPTIONS OF TAP TEMPO

Use the field study guide prompts to probe:

- ***Sway the Group*** → Do you notice any changes to the emotional tone or mood when the tempo is changed in a group listening session? (e.g., fast to slow, slow to fast)

- ***Call & Response*** → How does it feel to 'move' through the collective listening history archive through this more rhythmic form of interaction?

- ***Call & Response*** → Do you experience feelings of surprise or anticipation when you see others have started to introduce new tempo changes into the queue?

- When considering a tempo to tap, do you ever think about the kind of 'vibe' or emotional feel that music at that tempo might have before it plays?
    - What tempos would you select for activities like exercising, cooking, cleaning, reading, socializing, or simply relaxing?

- In general, what do you think about using tap tempo as an alternative way of navigating and exploring music to listen to? How does it differ from how you normally navigate, find, and play music on Spotify?
    - Did you notice any unexpected kinds of music being attached to tempo?

Appendix D. Queue Player Zine