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Encountering Cover Versions of Songs Derived from Personal Music-Listening History Data: a Design and Field Trial of Musée in Homes

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We designed and implemented Musée to capture the novel experience of interpreting cover versions of music, which contain both familiar and unfamiliar musical components and are curated based on the user's music-streaming history data. Musée is a tangible music player that enables users to explore and listen to professional or amateur covers of songs (via YouTube) in two categories: covers of songs from users' most-liked artists and covers of users' most-played songs. To investigate its potential value *in situ*, we conducted field trials of Musée in four households for 1 month. Findings showed that unfamiliar musical elements in cover music provided a sense of 'freshness' to past songs and helped the listener appreciate over-consumed music in new ways. In addition, restricting detailed information about cover songs that were playing helped users focus on the sound, thus priming them to infer and reflect on the original song and their memories associated with it. Our findings point to new insights for the design of interfaces that use historical personal data to expand users' experience beyond solely revisiting prior tastes.

RESEARCH HIGHLIGHTS

- Design and implement a device called Musée that can help users listen to cover music from artists or songs they like
- Understand the design process with regard to listening to and exploring their past music history in cover music through a tangible way
- Gather findings from a month-long in-field study of the device in participants' homes
- Provide considerations for designing a future system utilizing one's history data

Keywords: everyday artifact; field study; interactive device; unfamiliarity; music-listening history

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1. INTRODUCTION

Digital streaming services are introducing new opportunities and issues in terms of how they mediate people's everyday practices of creating, sharing and listening to music. Streaming-based music-listening platforms (e.g. Spotify and Melon) have opened up new possibilities for capturing and accessing years' worth of personal music-listening history data. Listening histories are one of the major byproducts of digital music-streaming services because they contain records of music that users have recently and frequently listened to, as well as changes in taste over time. Each data instance in a person's music-streaming history includes various kinds of each song's metadata, which include artist, play count, beats per minute and so on. In addition, these data instances contain contextual details, such as temporal and spatial characteristics (Chamberlain and Crabtree, 2016), of users' music consumption through the services in terms of when, where and how frequently users have listened to the songs. The accumulation of these music-listening histories is a crucial resource that can convey data-driven value (Elsden *et al.*, 2016a; Elsden *et al.*, 2016b; Odom *et al.*, 2019; Victorelli *et al.*, 2020), such as self-understanding of their musical taste, recommending new music the user might like.

Moreover, recent HCI studies have revealed that music-streaming history data can be used as design materials (Odom *et al.*, 2020; Wirfs-Brock *et al.*, 2020) and that users can tangibly explore music-listening history to support self-reflection and serendipitous experiences by triggering autobiographical memory in everyday life. Motivated in part by these works, we saw an opportunity to explore new design interventions to provide reflection-in-use with a new expression of personal data, specifically by applying a physical interaction that helps users explore their data archives and that provides a tangible feeling of control. Regarding the use of an individual's music-listening history data, prior research in Human Computer Interaction (HCI) and design had rarely translated users' metadata (e.g. frequently played songs or artists' music) into a specific derivative type of music (e.g. cover songs) through tangible interaction, which might provide new kinds of music listening experiences for end-users.

Thus, there is a need to look deeply into what types of diverse versions of music can be derived from users' music-listening history archived in their digital streaming service accounts. As the scope of media authorship has become broader due to music-sharing platforms such as YouTube, diverse versions (e.g. cover and instrumental version) of the same musical work continue to emerge and grow. For example, YouTuber J-Fla's cover of Ed Sheeran's "Shape of You" has been played more than 260 million times. Different from the digital music-streaming services, which contain only officially released music, the YouTube platform contains diverse expressions of the same musical work. Liikkanen and Salovaara (2015) categorized those expressions into three types: *traditional, user-appropriated* and *derivative.* In this, we discovered that providing *derivative* music, which refers to the altered version of previously recorded audio tracks, including novel elements in audio—also called a *cover* version of a song—from the metadata information (e.g. singer or song title) of an individual's music-listening history can be an interesting design opportunity to introduce a tangible device to users' everyday lives that offers specific encounters. This is because *derivative* versions of songs from users' listening history data may include not only familiar musical elements but also unexpected new elements, such as altered melody, different chord progression, change in tempo, new lyrics and even a shift in performed style or genre (Kishimoto and Snyder, 2016). In addition, those transformations come from the creators' own interpretation of musical work (whether the creator is professional or amateur).

Building on the understandings from previous studies, we found the potential value of investigating the methods of creating new music-listening and music-exploring experiences by utilizing specific elements of users' music history data. In part motivated by these insights, we aimed to develop a new design intervention that provides cover songs curated from the users' music-listening history data, specifically, information about users' favorite artists and frequently heard music. Accordingly, our goals in this study are to understand (i) how users perceive cover music derived from their listening history data (e.g. a frequently played artist and a song's melody) and (ii) how Musée made users diversify their music-listening experiences. To achieve these goals and ground our own thinking in this research space, we designed and implemented an interactive music player called Musée (Fig. 1). This tangible device contains three music plates. Users can explore each music plate by moving a tangible playlist tuner (dial) to select a certain plate and by rotating it to explore each list of songs in the plate. To investigate people's *in situ* experiences with Musée, we recruited four young adults living in different households who each had over 9 years of personal listening history data in their primary digital streaming services. We recruited participants who had a listening history of more than 5000 songs in their digital music-streaming service account. We deployed Musée in four participants' homes for 1 month. Our research makes the following contributions: first, this article introduces Musée and its design process, both of which provide implications for working with personal music-listening history data to support *derivative music* listening (of cover versions of songs) and to support such experiences in a tangible way. Second, it describes the results of a 1-month *in situ* study of Musée, providing insights into how participants accept and perceive music provided by the device, specifically from its physical interaction and their listening to songs embodying unfamiliar musical elements derived from participants' own music-listening history data.

2. RELATED WORK

Previous studies have explored how design interventions can open new opportunities for providing users' unexpected

FIGURE 1. Musée music player and the tangible playlist dial. The top image shows that Musée music player and the tangible playlist dial are placed on the music plate on the left playing cover songs (retrieved from YouTube), which were derived from song lists of the user's favorite artists (most frequently heard and liked) in his/her digital music-streaming service. The bottom images show examples of everyday use. The dial can be moved and attached to each music plate in order to play various types of cover songs or to hear the source music of the cover song

encounters with their personal data (e.g. music collection and photos) to provide an opportunity for a new interpretation of those contents. For this, HCI researchers have explored the use of personally meaningful materials such as photos (Leong *et al.*, 2011; Odom *et al.*, 2014; Chen *et al.*, 2019), music (Leong *et al.*, 2012; Dias *et al.*, 2014) and social content (Liang *et al.*, 2009; Hsieh *et al.*, 2011). Encountering and interpreting personally meaningful material could yield experiential value from serendipity and reminiscence. André *et al.* (2009) claimed that the effectiveness of serendipitous encounters relies on an ability to synthesize unexpected data into insight from the user's own interpretation. Also, they provided infrastructure that may support those kinds of insightful experiences. Relatedly, Liang (2012) presented three systems that give unexpected information that supports social interaction and experiences of reminiscence in daily routines.

At the moment of encountering unexpected information, a user's prior knowledge about the information can act as a hint for understanding the data and, further, positively shape their own interpretation of the data (Toms *et al.*, 2000). Recent studies have shown that serendipitous experiences can also be triggered by helping users encounter music that they had heard or photos they had taken in the past. In this context, Odom *et al.* (2019) proposed a tangible music player that allowed users to re-experience previous music in their listening history. Similarly, Chen *et al.* (2019) proposed a device called Chronoscope, which helped users explore their past photo archives through and across time in a scope-like form. These attempts utilized physical interaction (i.e. rotation of the disc and adjusting scope) for users' manipulation and exploration of their past heard music and taken photos, which could be a resource for evoking autobiographical memory—"memory for the events in one's life" (van den Hoven and Eggen, 2008, p.1). In addition, Nam and Kim (2011) mentioned that physical manipulation helps users engage in narrative interpretation of serendipitous information they encounter. In an exploration of how to attract and stimulate users, Dumas *et al.* (2014) remarked that tangible interfaces made users feel more confident. Previous studies on designing systems to represent personal data highlighted that the physical presence of data in a user's daily environment could increase accessibility to data by providing a subtle visual cue (Jansen *et al.*, 2015), which could guide users to interact with the device (Norman, 1999).

Moreover, the physical interaction offered by tangible object manipulation could provide a hedonic feeling, emphasizing sensory engagement (Nam and Kim, 2011; Sax, 2016). These strands of previous research imply that tangible everyday objects that physically explore users' past data could catalyze unexpected encounters leading to new perspectives or discoveries hidden in these records. In addition, these records could trigger open-ended thoughts through daily engagement with the data-representing devices that enhance a particular daily moment (Van Campenhout *et al.*, 2013).

From the point of view of the music-exploration experience, Hosey *et al.* (2019) explained that users search for music with a focused mindset so they can gain information about specific music. At the same time, users can also accept open suggestions with an *exploratory mindset*, which allows them to recommend new music to users. Similarly, other studies have proposed ways to curate new music based on users' moods (Andjelkovic *et al.*, 2019) or to revisit (Odom and Duel, 2018) the music they had heard in the past by analyzing their previous music-listening history. The suggestions from existing music-streaming services (e.g. Spotify and Apple Music) used in the above studies were mainly made within one service, which contained only officially released versions of music. However, there are numerous versions of music, categorized by Liikkanen and Salovaara (2015) as *traditional, user-appropriated* and *derivative* based on audio, video, subtitles and annotation embedded in a YouTube music video. More specifically, *traditional* refers to single-released (authentic) versions of music videos, whose corresponding songs were usually offered by the digital streaming services. *User-appropriated* refers to music that maintains the audio of single-released versions but with embedded user-created elements, such as fan-made illustrations or still images related to the artists. Lastly, *derivative* refers to altered versions of previously recorded audio tracks, including novel elements in audio (e.g. different voice, tempo, pitch or instruments) inspired by *traditional* types.

In this study, we focused on providing *derivative* versions of *traditional* music because they could provide various experiences through altered elements (e.g. chord progression and tempo) while maintaining semantic similarity to a single-released version (the musical work itself; Serra *et al.*, 2010). Collectively, our work attempts to bring these strands of research together through the design of a tangible music player and to explore the experiences through field deployment studies. We believe that curating derivative music based on the user's listening history data through physical interfaces could potentially create an opportunity for them to discover unexpected data. Specifically, we will investigate how technology can be designed to provide user experiences of listening and tangibly exploring derivative music that contains musical elements familiar to the user and that is extracted from the listening history data. Furthermore, our research findings may open up new design opportunities for media-supported reflection through users' past data and serendipitous experience from new musical elements in derivative types of music. Next, we describe the design of Musée, with attention to how we selected derivative music with user-familiar musical content and applied it to Musée's interaction design.

3. BACKGROUND, DESIGN RATIONALE AND IMPLEMENTATION OF MUSÉE

Music as a medium could easily be diversified by changing or twisting musical compositions in creative ways. Through numerous performers' interpretations of existing music, they fill the texture of the music by transforming melodies, chord progressions, lyrics or even the genres or styles intended by the composer to create numerous musical expressions of the same musical work (Kishimoto and Snyder, 2016). With a digital platform like YouTube, it is possible to easily share these different versions of expression in forms of derivative music, which contain slightly different musical elements, and make them pervasive (Cayari, 2011). It enables and encourages users to create various music contents for listening purposes, despite the boundaries of being a video-streaming service (Liikkanen, 2014). Furthermore, in this environment, new opportunities have emerged for a wide range of musicians, including amateurs and professionals, to cover previously released music and express their own interpretations on them. Consequently, compared to digital music-streaming services (e.g. Spotify in USA and Melon in Republic of South Korea), which only contain officially released music by corporations, YouTube includes derivative types such as covered and remixed music (Liikkanen and Salovaara, 2015).

For this, we investigated the notions that describe the versions of intellectual works (e.g. music) to understand the various versions of songs and relations among them. In this respect, we found that FRBR (Functional Requirements for Bibliographic Records) was created to address the issues that came from the various versions of intellectual and creative works. FRBR suggested a set of four entities: *work*, *expression, manifestation* and *item* (Madison *et al.*, 1997). As applied to the subject of music, *work* refers to musical composition, *expression* refers to performances of composed music, *manifestation* refers to the physical embodiment of expression (e.g. CD and audio tape) and *item* refers to a single exemplar of a manifestation (e.g. a single audio tape). In this, various performances (*expression*) of the same composition (*work*) can exist through the different performers. In other words, various expressions of a work can be explained as various versions of a song that contains variations of musical components. Most of these musical media are also listening-oriented videos that can be consumed without viewing the image displayed on the screen. In this, we expected that the derivative type of music (i.e. cover song) could provide new experiences through the feelings of familiarity and unfamiliarity that coexist in the music when it is heard by the users. As the familiarity comes from user-familiar musical components (e.g. a favorite artist's voice or a melody of a frequently heard song), unfamiliarity can be felt by altering other familiar musical components—for instance, by providing a different song performance (not in the artist's album) of the user's favorite artist or a cover song reinterpreted from another singer. Through this approach, the tension created between these modified elements can catalyze users' new interpretations of music. It can also lead to unexpected discovery and reflection while listening to those derivative types of music.

Thus, we designed Musée to capture the novel experience of interpreting public-generated cover versions of music, which contain both familiar and unfamiliar musical components and are curated based on the user's music-streaming history data. For this, we utilized users' digital music-streaming history data in Melon, which is one of the representative online music-streaming services in South Korea. Within the data, we extracted two musical elements familiar to the user (users' favorite artists' songs and their most-played music) to provide various types of cover songs. Through this approach, we expected that these cover songs would provide unfamiliar feelings through the various artists' vocalizations of the users' most-played songs or different songs' melodies sung by the users' favorite artists. Additionally, previous studies (Odom *et al.*, 2019; Odom *et al.*, 2020) have shown that metadata (i.e. listening history) can be a resource for users to not only record their musical activity but also reflect on life experiences. Based on this, we also wanted to enable users to revisit their music-listening history along with its derivative cover versions to support them in reflecting on music. To explore the above new dimension of experience, we designed a physical music interface that allows users to tangibly explore and listen to songs provided by the device, which we elaborate on in more detail next.

3.1. Design and implementation of Musée

To integrate our background research, and rationale into a suitable artifact that inquires into people's real-life experiences, we adapted Research Through Design approach (Zimmerman *et al.*, 2007) for developing the Musée concept. In designing the Musée concept, we wanted to trigger the use of Musée through a device's physical presence (Mols *et al.*, 2020) in users' living environments—in effect, embodying their largely placeless and formless listening history data in a tangible form that can be lived with and experienced over time. In this, we aimed to support users in exploring, selecting and engaging with curated cover music through tangible interaction. Thus, we focused our design direction on (i) fitting the form of the musical device (Odom *et al.*, 2016; Jang *et al.*, 2019) to the surrounding environment (e.g. by merging the electronics with the frame, floor/desk object, or a wall shelf) and (ii) facilitating tangible interaction, which may provide users the feeling of sensory engagement as they explore their past heard music through cover versions.

3.1.1. *Design process*

Based on the above design directions, we developed Musée. We started by investigating various ways of providing physical interaction (e.g. tangible dials/plates, plate movement or an indicator handle) to explore three music plates in one device. We devised more than 80 concepts (see Fig. 2) with variations of sketches, such as (i) an LP metaphorical design enabling the user to change the cover music plate (vinyl metaphor) and explore cover music through a moving needle, (ii) a fixed cover music plate and moveable frame for exploring cover music and (iii) a fixed music plate and attachable tuner for exploring cover music. Among many sketches, shapes and interaction methods, a fixed music plate with an attachable tuner emerged as best fitting our design direction, especially considering our goal of stimulating users' senses via a tangible interaction method. We thought this model would be easy to manipulate and could provide users ample sensory engagement through its attach/detach and rotating action. Also, we considered our design to have a multi-plated form, which represents two derivative types of music playlists in each left and right side of the music plate. Plus, one additional plate is located in the center, which is used for the confirmation of source music of a certain derivative song that is currently playing in either the left or right music plate. Thus, we positioned this prototype of our three musical plates with a tangible dial deprived of a bezel in a horizontal line, and we inserted a parting-line gap to divide the whole body. After arriving at the final Musée design, we adjusted the design details using renderings and mockups (Fig. 2) to provide visual attractiveness (Minge and Thüring, 2018).

FIGURE 2. Design process of Musée. (**a**) Variations of concept sketches, (**b**) renderings or preselected design and (**c**) Final design.

3.1.2. *Playlist dial: the tuner*

We carefully designed the tangible playlist controller (Fig. 6) in a way that stimulates users' sensory engagement as they interact with the device by selecting music plates and browsing cover music. From among several ways to browse music—using scratches, knobs, parameters or buttons—we chose to shape the controller as a dial. We also wanted to convey haptic feedback during rotation of the dial during music exploration interaction. This feedback was intended to give users the feeling of manipulating the scale of information, including the lists of cover songs derived from their music-listening history. We implemented the haptic feedback by testing various types of mechanical structures (Fig. 6a). Our first prototype was a dial-shaped case of the rotational potentiometer, which did not provide enough mechanical feedback. We utilized a rod tensioned against a gear to provide more sensory engagement, which created tactile feedback (sound and vibration). However, this structure did not provide two-way rotation (only enabling clockwise rotation), and it was not well suited to the music exploration function (i.e. choosing next and previous songs). We finalized the dial design to resolve this shortcoming, providing two-way rotation and tactile feedback with two pairs of gears and rods (outer for clockwise rotation and inner for counter-clockwise; Fig. 6c). It also provided bidirectional haptic feedback and augmented *feedforward* (Wensveen *et al.*, 2004) of the next and previous songs in the playlist. Within the user's choice of a music plate, we intended to offer a more integrated interaction experience (Campenhout *et al.*, 2016; Kim *et al.*, 2018) when browsing any song at a given time point in temporal order through this dial. We added light indication to give feedback about where the user's previous and current action occurred as they rotated the dial to explore music.

FIGURE 3. Interaction of Musée

3.2. Interacting with Musée

First, in idle mode, users can navigate between the music plates by placing a dial onto each plate (Fig. 3). The dial's positioning represents the user's music plate choice, and the position of the LED light represents the current browsing position of the plate. Browsing a playlist by rotating the dial is only possible in the left and right plates. To deliver the center plate is only to check the source music of the derivative music, and this forces the users to focus on exploring the left and right plates. Once the user positions the dial onto the left or right music plate, the LED light will point to the 12-o'clock position, which informs the user that it is ready to play music. We did not include any digital screen-based display to show the music information (e.g. music title or artist) when users are exploring the music plates. This was to help users focus solely on facing the derivative music and switching between the music plates (i.e. providing inherent feedback through the dial's haptics sound and the location of light) in order to further prompt creative interpretation and reflection.

Different music from favorite artist: Left music plate (Fig. 4) plays derivative music posted on YouTube based on users' favorite artists who were given the most "like counts" (a way to express likeness to given music) by the user on the Melon Digital Music–streaming service platform. The derivative music in the left music plate contains playlists of different music performances created (or just sung) by the user's favorite artists. The description "different music performances" means the music is not in the artist's released album and is from various other artists. For instance, if Jason Mraz is one of the user's favorite artists, the left music plate contains and plays "Let It Be, Beatles," sung (or performed) by Jason Mraz. By moving the dial onto the center plate while the music is being played, the source music (Let It Be, Beatles) of the derivative music will be played. To retrieve the derivative music versions, we used the YouTube platform. In this music plate, all music is listed from the highest to lowest favorable artists' derivative music in clockwise order.

Different voice in frequently heard music: The right music plate (Fig. 5) plays derivative music posted on YouTube based on users' most-played music in Melon. This type of derivative music is called "cover music" in general, and we retrieved those songs from YouTubers' (YouTube content creators') channels. The selection criteria included a high number of view counts when searched and sorted from highest to lowest within a YouTube search algorithm. Thus, the derivative music of the right plate in Musée contains playlists of users' most-played songs that are performed (or sung) by various pro/amateur artists. For instance, if the frequently heard song is "Ben, Jackson 5," the right music plate contains and plays "Ben sung by Billy Gilman," which has the highest view count in YouTube among other versions. Using this, we wanted to provide users a feeling of familiarity from their frequently heard music and a feeling of unfamiliarity from the other artists performing users' most-played music. In this plate, clockwise rotation of the dial will enable users to navigate from the most recent to the previous songs in their listening history. While music is being played, by moving the dial to the center plate, the source music (e.g. "Ben, Jackson 5") of the derivative music is played.

3.3. Implementation

We implemented each musical plate by including an LED light strip and a magnetic Pogo pin connector (Fig. 6a) to make a physical contact point between the tuner and plate and to give the user a visual indication of its operation. For this, we programmed the dial's rotational motion to cooperate with the LED strip, thus indicating what portion of the music is currently being browsed by the user. All light indications are controlled by an Arduino Pro Mini, and the referencing timeline is controlled via serial communication with a Raspberry Pi Zero, which holds the music playlist for each plate. When the rotary encoder inside the tangible tuner connects with the Pogo pin of a certain music plate, regardless of the signal that was triggered via the user's rotational input, the first song in the playlist will play through a 3-W speaker located inside the device. All of the Musée's electronic components are integrated onto a custom PCB (printed circuit board) and within a slim external body enclosure (Fig. 7), which enables the artifact to be used in a wall-holding or desktop-standing position.

4. USER STUDY

To examine how people would use Musée in everyday life and engage in musical experiences, we used the prototype in four participants' homes (three shared, one individual) for 1 month. Similar to the aim of the original technology probes paper (Hutchinson *et al.*, 2003), including several field studies since then (e.g. (Gaver *et al.*, 2006; Gaver *et al.*, 2007; Pousman *et al.*, 2008; Odom *et al.*, 2014), we initially selected and focused on a smaller number of households to gain a richer

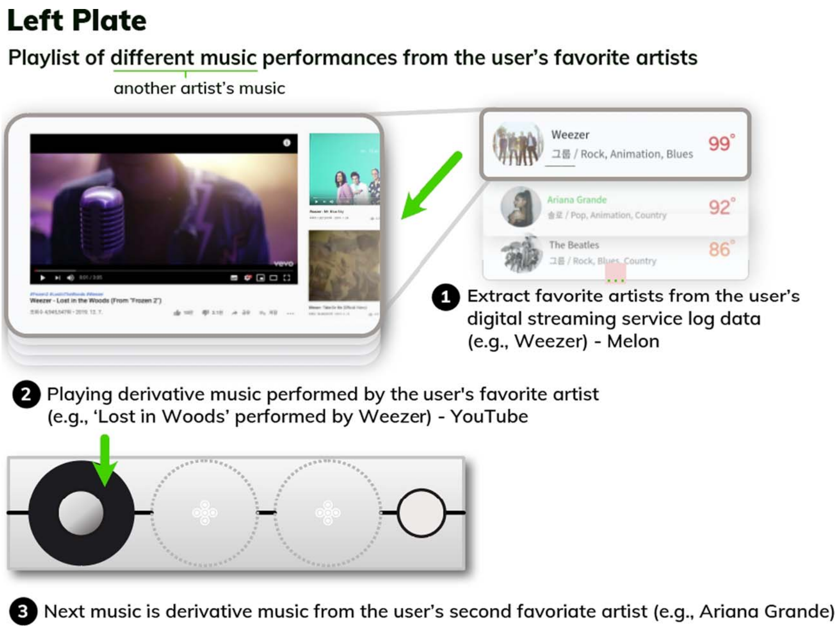

FIGURE 4. The left music plate of Musée

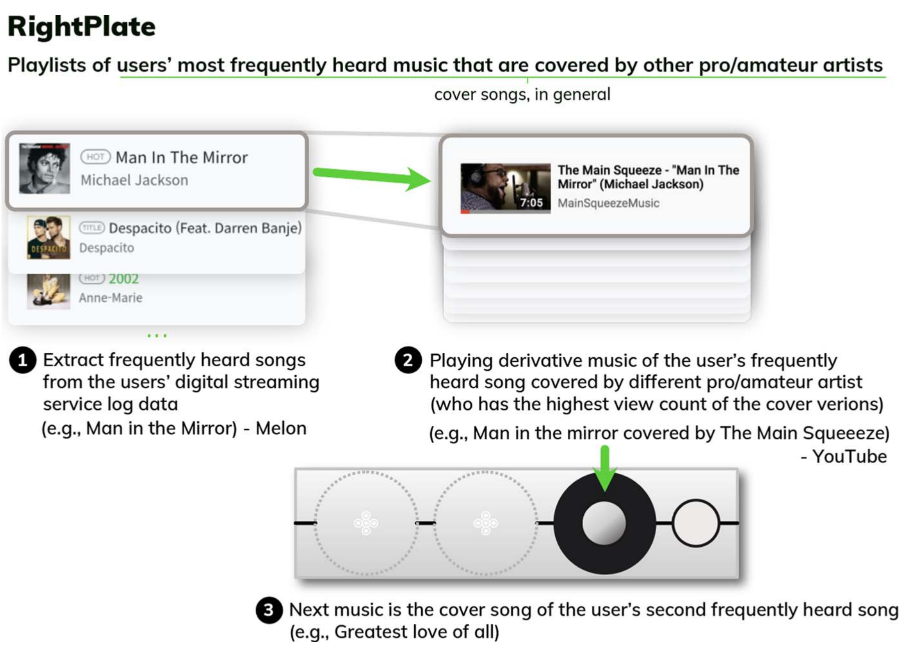

FIGURE 5. The right music plate of Musée

descriptive understanding of the space as a whole, which informs potentially salient issues for future research. In particular, we wanted to identify (i) how a tangible music player that curates derivative music from users' music-listening history might be accepted in their everyday living environment and (ii) how unfamiliar musical elements in derivative music, derived from users' past data, affect their music-listening experience. In addition, the study was conducted before COVID-19 had actively begun to spread in South Korea.

4.1. Participants

We recruited participants who had extensive music-listening histories through the Melon Digital Music–streaming service—

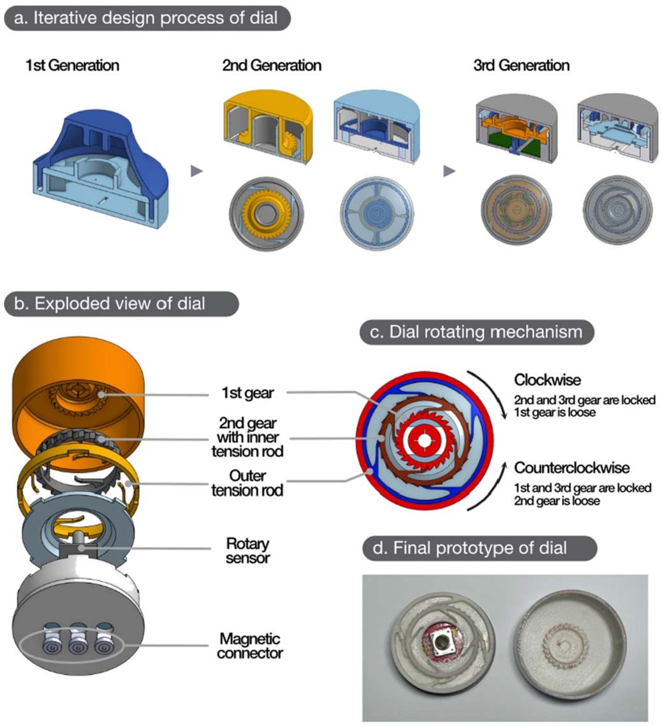

FIGURE 6. The design of dial. (**a**) Three dial outcomes from iterative design process, (**b**) the exploded view of dial, (**c**) the mechanical structure of dial and (**d**) the final prototype of dial.

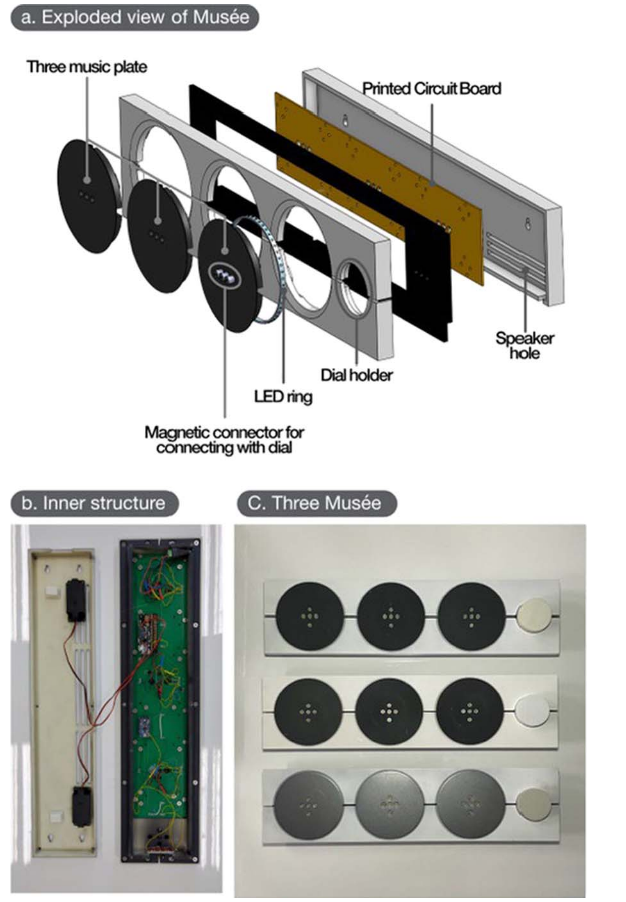

FIGURE 7. Hardware implementation of Musée. (**a**) Musée's exploded view, (**b**) the inner structure of the Musée prototype and (c) three Musée prototypes built for field study.

in particular, those people who had more than 9 years of Melon use data and had listened to more than 5000 songs using their account. Melon saves diverse records of users' music-listening history (e.g. number of songs heard and most-liked/most-played artists) from their smart devices and desktop computers.

For recruiting participants, we posted flyers and advertisements in digital community platforms, such as Facebook and Everytime (Korean Domestic University Network Service). They included QR codes, which linked to enrollment and pre-survey to the experiment, and a simplified explanation of the research. We created a pre-survey to ask the participants about their music listening patterns, past experiences related to cover music and questions about their respective past use histories with Melon, a Korean music streaming service. Based on this response, we decided participants who had a substantial amount of listening history since Melon started the service in 2004. We selected those who had 9 to 14 years of listening history and had a periodic listening history of at least a few songs in a month. The participants consisted of one man and three women (referred to as P1 through P4). Their detailed demographic features are as follows.

Household 1 consisted of P1 (male, aged 23 years, 10-year Melon member who had played 5405 songs so far). He lived with his housemate (male) in the same apartment where we deployed Musée. He conducted piano concerts on a regular basis and managed his own YouTube piano channel. He often plays along on his piano when good music comes out of his speaker.

Household 2 consisted of P2 (female, aged 23 years, 11-year Melon member who had played 7041 songs so far). She lived alone in a studio apartment. She did not have much experience related to music (e.g. joining a music club or playing an instrument).

Household 3 consisted of P3 (female, aged 18 years, 9-year Melon member who had played 5053 songs so far). She lived with her roommate (female) in the same room where we deployed Musée. She graduated from a music-centered middle school. She had experience performing in a piano concert during high school. Currently, she is a member of her school's piano club.

Household 4 consisted of P4 (female, aged 29 years, 14-year Melon member who had played 20524 music so far). She lived in a two-bedroom apartment with her boyfriend. Among the

TABLE 1. Number of cover songs identified based on the four participants' log data for the left and right music plates in Musée

	No. of identified cover songs (not in the favorite artist's album) performed by the user's favorite artist: **playlist of left music plate**	No. of identified cover songs of the user's frequently heard music covered by different pro/amateur artist: **playlist of right music plate**
P1	**212**	**300**
P2	**215**	**286**
P3	**229**	**278**
P4	**231**	**300**

participants, she had used the streaming service for the longest time and listened to the most diverse music.

4.2. From participants' music-listening history data to cover songs in YouTube

After recruiting four participants from each household, we extracted the logs of their most-played music for each month of the previous 5 years, along with the 20 most-liked artists from each user's Melon account using Python web crawler (i.e. Selenium). We selected 300 songs in chronological order from the users' log data and another 300 songs from the 20 artists selected (15 songs per artist). We then mapped the corresponding YouTube URLs to connect cover songs to each song extracted from Melon account. Cover songs were selected based on the highest view counts for each song on YouTube (Fig. 9).

If the song did not have a cover version, it was excluded from the playlist. As a result, we retrieved and provided the following numbers of derivative music to each participant (Table 1).

4.3. Deployment and data collection

Each participant used a Musée for 1 month. We declared it is not mandatory to listen to music through Musée, and let them position it wherever they want and use it as they desire to. One day before the user study started, we visited each participant's home with a Musée, two dials (including a spare) and a user manual. After installing Musée in the users' environment (Fig. 8), we gave simple instructions to familiarize the users with Musée. We conducted weekly interviews (from week 2) during the study; additionally, we performed pre- and post-use interviews. All of the interviews were semi-structured. Each interview lasted ~30 min, and the interview contents are summarized in Table 2. In addition, Musée logged the date, time, music title, selected music plate and dial selection frequencies for all music that was played in Musée. These data were used to identify which songs were played and when from each of the three music plates during the field study. Log data for P3 could not be collected due to an error of the logging system inside Musée. To compensate for this, we asked P3 an additional interview question to replace the log data and used it to analyze the results.

4.4. Data analysis

To analyze our data, we used an approach based on Clarke and Braun's (2014) Thematic Analysis. We transcribed all interviews and read the recordings multiple times to familiarize ourselves with the data. Then, we generated initial open codes that we considered meaningful and interesting. We classified our initial codes by looking deeply into the relationship between the codes, and during the process, we focused on the codes that were related to overall usability, physical interaction while exploring the music plates and the experience of listening to songs provided by Musée. We then designated 14 subthemes that we considered the most meaningful and most relevant to Musée and reviewed the themes with two additional researchers who were not involved in the interview sessions to offer a naive observation of the data and extract important themes. Through this process, we could create thematic connections between the open codes and derive six key themes. Figure 10 shows our overall process of interview data analysis.

5. FINDINGS

We analyzed the participants' various music-listening and interaction experiences of using Musée for 1 month. Our analysis process resulted in six different sub-groups (themes) based on our coding, which we then used to distill three key findings. In what immediately follows, we provide brief explanations of the six different themes that we arrived at through our data analysis.

1) *Providing freshness to over-consumed music:* The unfamiliarity of cover music provided a subtle difference from original music and offered users a sense of novelty for music they had already heard, even though it had been over-consumed.
2) *Arousing curiosity:* The cover music is derived from listening history data, which triggered curiosity because it contained both familiar and unfamiliar musical elements.
3) *Balancing familiar and unfamiliar feelings in cover songs:* The unfamiliar feeling is derived from three different factors in cover music, necessitating a careful balance between familiar and unfamiliar musical elements.
4) *Inferring unfamiliar musical elements through focusing on only sound:* The users felt curious about cover music, which made them focus on their music-listening behavior and attempt to infer familiar musical elements through deep listening.

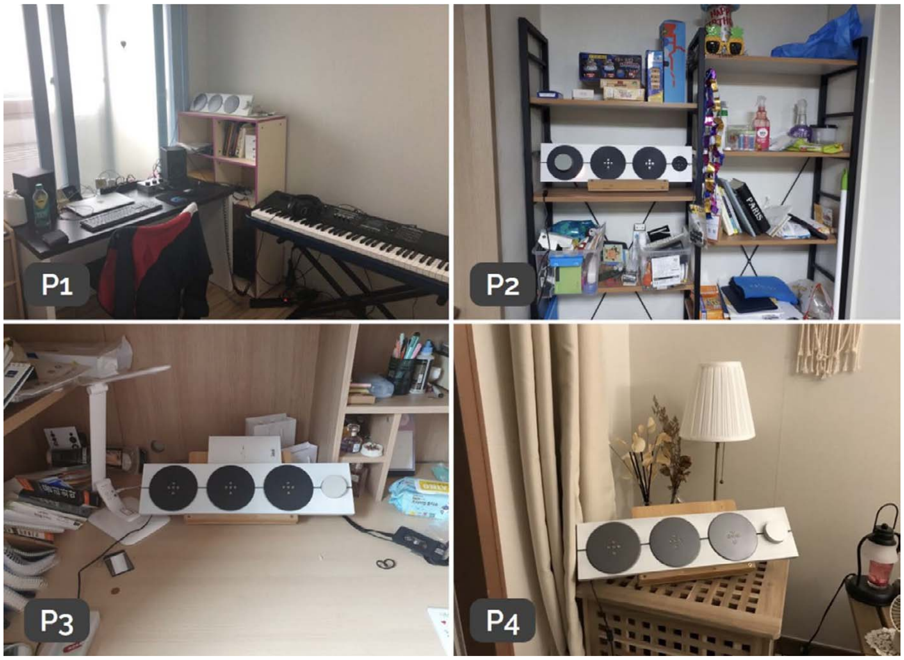

FIGURE 8. Musée *in situ*. (**a**) P1's room in a shared apartment, with Musée placed on the top of his bookshelf; (**b**) P2's studio apartment, with Musée placed in a bookcase; (**c**) P3's shared room; and (**d**) P4's apartment, with the device on her bedside table.

TABLE 2. Summary of the interview subjects during the study

Interview week	Interview contents
Before the deployment	Previous experience in listening/browsing/collecting cover versions of music
	Habits of music consumption
Week 2	Comparison of cover music (with Musée) with the officially released version of songs (in digital music–streaming services)
Week 3	Physical engagement and interaction of Musée
	Only in Week 4
Week 4	Period of music updating within Musée with history data
	Other remarks and suggestions (e.g. types of derivative music, ways to expand original songs)
Post-use interview	How they searched for derivative music
	Ways of listening to music

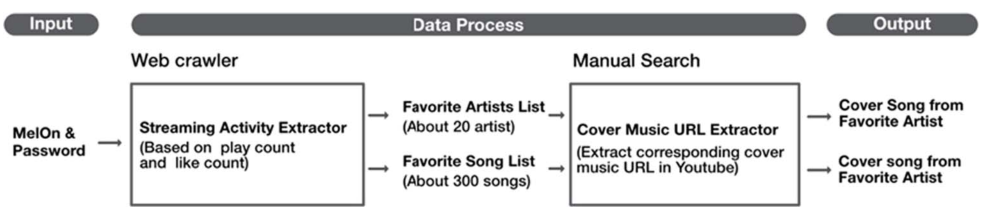

FIGURE 9. Process of converting a user's listening history into a playlist of cover versions of the music

5) *Understanding the cover music in a new way:* Musée offered the participants a new way of understanding derivative music, which enabled new experiential pathways for them to value music productions by both professionals and amateurs.

6) *Adapting to Musée in users' living spaces:* Musée's required physical interaction and presence affected the music-listening and selecting experience.

Based on these six themes, findings from our field study break down into three key areas. First, "understanding the

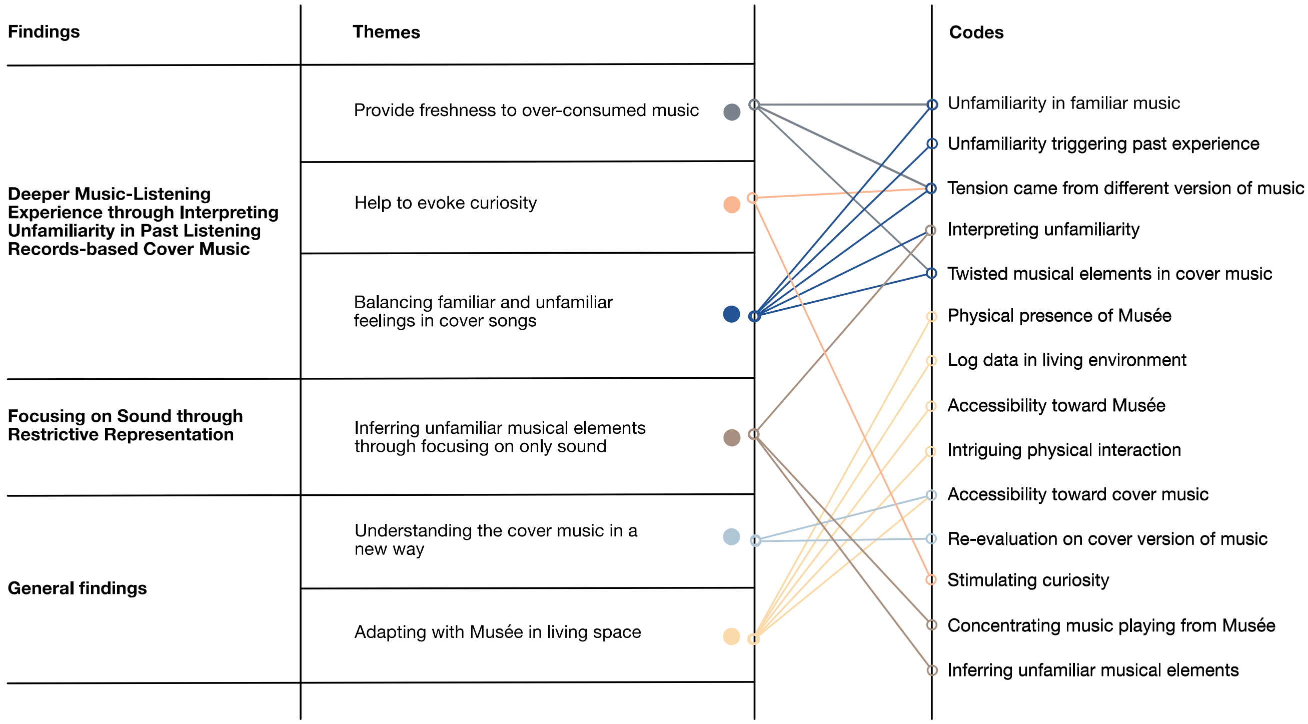

FIGURE 10. Comprehensive process of qualitative data analysis

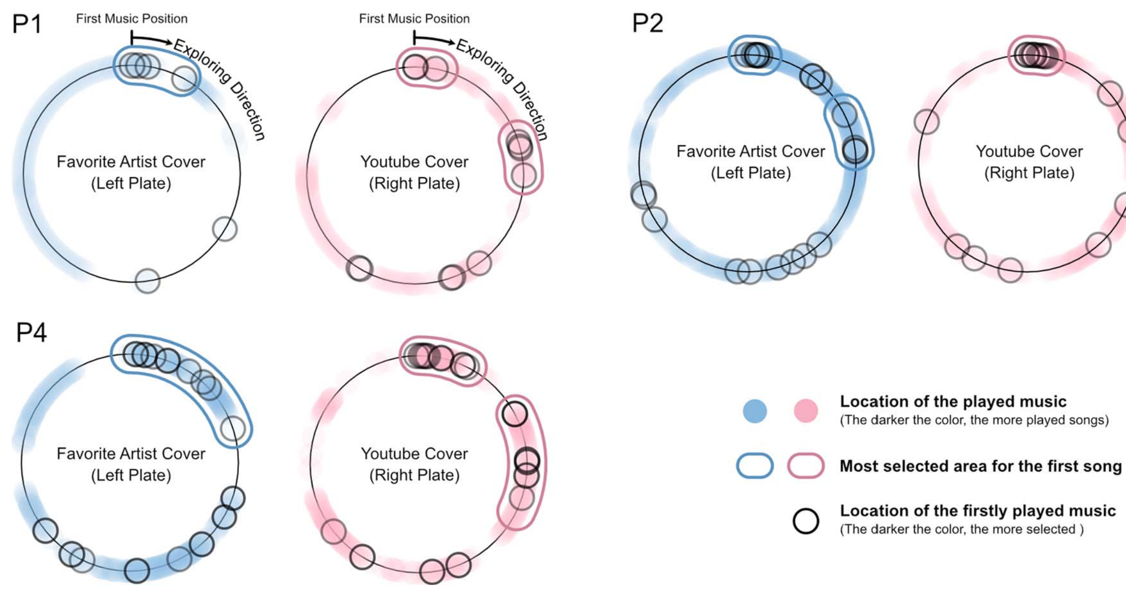

FIGURE 11. Heat maps represent the location of the music played through the Musée. The colored circle represents the position of the played music, and the darker the color, the more the played position; a black outline is a location where the user first plays music, and an area frequently selected for the first time is expressed as a colored outline.

cover music in a new way" and "Adapting with Musée in living space" shape the general finding (subsection 5.1), which concerns how the participants adapted Musée and used it in the daily environment and how Musée affected their music-listening experience. The second finding (subsection 5.2) was derived from the themes "*providing freshness to over-consumed music*," "*helping evoke curiosity*," and "*balancing familiar and unfamiliar feelings in cover songs*." This finding

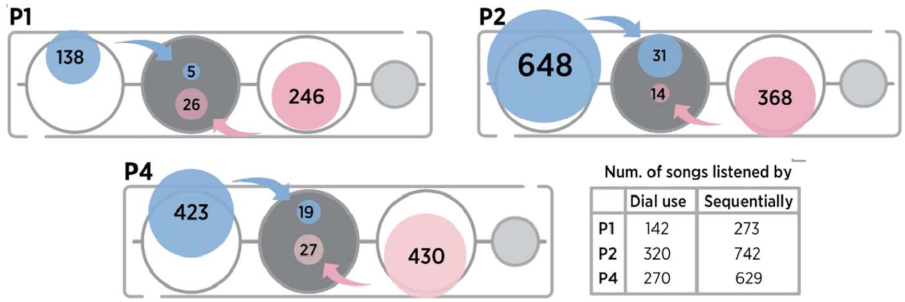

FIGURE 12. Total number of usage log data entries for P1, P2, and P4 during the month. The numbers in the blue and red circles show how many songs they listened to from each music plate. The smaller circles in the center and the accompanying arrows indicate how many times users moved the dial to listen to the original music

provides insight into how users perceived which experience could be delivered via a familiar musical element in cover music derived from their music-listening history data. In addition, there were consideration points for curating cover music based on music-listening history data. Lastly, in subsection 5.3, derived from "*inferring unfamiliar musical elements by focusing only on sound*," we provide insights specifically surrounding the design feature of Musée that provides only the sound of cover music without any additional information, which was shown to shape the way participants listened to music. Next, we explain each key finding in detail.

5.1. General findings

We confirmed that the participants turned on the Musée device about 1.43 times (P1: 1.1 times, P2: 1.5 times, P4: 1.7 times) on average on the day they listened to music via Musée. Also, we confirmed that the participants listened to music via Musée continuously for ~2 hours (P1: 1 hour 30 min, P2: 2 hours 18 min, and P4: 2 hours 14 min) when they turned it on. Furthermore, through log data analysis, we confirmed that the first song that the participants listened to through Musée was influenced by the location of the music plate (the front song was mainly selected; Fig. 11, colored outline). Nevertheless, it was confirmed that most of the participants listened to the music evenly overall (Fig. 11, colored circle). From the weekly interviews, we also confirmed that the participants became familiar with the use of Musée during the second week of the study. P1 stated, *"In the first week, I used it to check if it (Musée) was working well, but after 3 weeks, I listened comfortably, thinking about whether to listen to my favorite cover or the artist's cover. I think I use it more actively."* Furthermore, the tangible interactions of exploring music prompted participants to manipulate the Musée. Three participants noted that the natural vibration and sounds produced by the dials had a positive effect on the music browsing experience once participants were accustomed to the use of the device. P1 mentioned that the sensory engagement felt when turning the dial or attaching to the main device's body made enjoyable interaction. In the third week's interview, *"The click sound (from the dial) and, I think, the magnetism that occurs when you move the dial to another plate is the aspect that makes me use and enjoy this speaker (Musée)."*

More specifically, interactive features of Musée include a dial, which users can move around to each plate, providing visual stimulation during the control. P3 noted, "*[through the physical plate and dial] I felt that it gives me a visible option: when I want to listen to original music (which is embedded in the center plate), I move the dial to center, and when I want to move from one artist to another artist, I rotate it. Then I just thought, 'I should listen to this!' (when rotating the dial). It also gives a clicking sound."* We confirmed the use of these characteristics through the Musée's software log (Fig. 12); approximately one-third of the total playback was played through the participants' dial manipulation, although they could leave the dial for automatic play after one song ended. The participants also checked the source music after they listened to derivative music for an average of ~5% of the total music played from each side plate. The device's presence in the users' living environment helped them notice the possibilities of physically interacting with a music-data artifact, which positively affected the likelihood they would encounter the cover versions of songs.

Moreover, we discerned that the use scenarios of Melon and Musée were situated differently. Previously, all participants used Melon to find the song they wanted to listen to, and three participants (P1, P3 and P4) used thematic playlists to listen to music when they did not have a particular song they wanted to listen to in the moment. Also, some participants (P1, P2 and P3) showed the behavior of not listening to music they liked in the past through Melon, but rather listening to new music they could find, due to their lack of awareness about the functionality of the Melon.

In this context, Musée was designed to help users more easily re-experience their favorite musical content in the cover version. Moreover, the participants used Musée to "fill the space" when their living quarters seemed quiet. Regarding this, P2 stated, *"I usually watch TV when I do housework or shower,* *but now I use this [Musée] instead. I haven't watched TV for two weeks. When I'm alone, I used to watch TV because it's quiet, and if it is not fun, I keep turning to other channels. Musée is better than TV because the songs are the things that I used to enjoy listening to."* P3 also remarked, *"I listen [to the Musée] when I'm with my laptop and also when I'm preparing for something. It's quiet when I'm alone, but with the derivative song from Musée [a radio cover], it's less quiet because I can hear people' sounds and hear music too. When I'm alone, this makes for not a quiet atmosphere but a brighter atmosphere."*

Moreover, the music provided by Musée reduced negative presuppositions about cover music by providing users' favored musical elements (e.g. familiar melodies or voices), thereby encouraging the user to listen to cover music more. Three particular participants (P2, P3 and P4) had not listened to cover music at all, stating that they had a negative stereotype about it, but after the field deployment of Musée, we found out that this prejudice was diminished and that their thoughts had changed regarding cover music. For instance, P3 noted, *"The songs from Musée are the song that I usually listened to. It makes me concentrate on the music itself.... I can listen to different feelings from the original song, and I think it was an opportunity to remember the song I had heard before. [Previously,] I've never heard of the public covering certain songs, but through Musée, I can listen to music in various ways, with variations of chords, instruments, and voices."* P4 mentioned that she did not usually listen to cover songs. However, through her use over the course of the month, she noted that her perception had changed: *"Previously, I wondered why I should listen to a cover song because I could just listen to the original song. But now [fourth week], I've changed to be a bit on the positive side. Rather than just listening to it for no reason, I feel like I want to hear it, browse for it, and think about the cover version of this song."*

We found that the music-listening experience through Musée is affected by the presence of familiar musical elements and unfamiliar musical elements. The following section will explain how users perceive those un/familiar experiences and which kinds of music-listening experience could be provided through Musée.

5.2. Deeper music-listening experience through interpreting unfamiliarity in past listening records-based cover music

Although music provided by Musée contains users' favored musical elements based on their listening history, we found that the participants felt subtly different feelings in response to these elements. Also, these elements supported them in re-conceptualizing songs they had liked and had frequently listened to in the past.

P2 noted, *"The music was not new, but I feel it is new again, and that makes me listen to it. The music in Melon is songs that I have listened to many times, which makes me tired of listening to them. But this [the cover songs in Musée] is a new thing. I am tired of the original music. However, I still like it, so this makes me find the covers."*

We also identified how the familiarity and novelty of cover music could provide diverse music-listening experiences for the participants. P1 mentioned, *"When I found good music while just listening, I was pleased when I knew if he [the artist] had ever sung this music. When I was listening to the music by the artist [the left plate], it was my first experience knowing that my favorite artist has covered music . . . . Also, when the other singers covered music that I knew, it was amazing to be able to sing this music with this feeling."* During the field study, we confirmed that Musée provided diverse music-listening experiences for the participants via subtle differences between the version they had listened to before and the transformed musical elements in the cover music.

In the following subsections, we explain how unfamiliarity in the cover music retrieved with the aid of users' music-listening history data in Melon affected the diversity of their music-listening experiences. We also describe points to consider in delivering appealing cover music identified with users' music-listening history data in Melon.

5.2.1. *Providing different lenses for listening music from past data*

We identified how unfamiliar musical elements produced different music-listening experiences. Specifically, three participants mentioned that the listening experiences provided by Musée helped them think about songs in their music-listening history in new ways. P3 noted, *"[The music from Musée is the music that I usually listened to.] It makes me concentrate on the music itself. . .. I can listen to different feelings from the original music, and I think it was an opportunity to remember the music I had heard before. [Previously,] I've never heard of the public covering certain music, but through Musée, I can listen to music in various ways, with variations of chords, instruments, and voices."*

Provide freshness to over-consumed music. Every participant mentioned that unfamiliar musical elements in the cover music made them feel the music was new, even for the music they have grown tired of due to frequent listening. We confirmed that introducing the right amount of unfamiliarity to users' favorite, but over-consumed, music added freshness to the listening experience. P2 noted, *"It was music that wasn't new, but I feel it is new again, and that makes me listen to it. The music in Melon is the songs that I've listened to many times, which makes me tired of listening to them. But this [the derivative music in Musée] is a new thing."* Three participants also stated that listening to cover music made them want to hear the original song again. P4 said, *"I listened to verse #1 through cover music, and when verse #1 ended, I turned it over to the original music (moved dial to center plate). I think I tend to find the original music because the cover music feels a bit unfamiliar."*

Help to evoke curiosity (and infer them): Additionally, we found that unfamiliarity in the cover music triggered the participants' curiosity. P1 mentioned, *"I was very focused when there were songs I never heard before and curious about, 'what is this song?' when listening to it as background music,"* Similarity, P4 mentioned, *"What is this song? I have known this song but sung by a different person, and that makes it like a different song, and I was very curious about it."* This curiosity led participants to infer unfamiliar elements in the music and, in the process, familiar elements in cover music acted as hints. P1 noted, *"Officially released songs are easy enough to search with smartphones, but we cannot simply find cover music that well. In that case, when I have a slight guess about who the artist is, I used YouTube to find out by searching about both original artist's name and title, which I found using a music searching engine."* P2 also found cover music using their favorite artist's name and the song title, which their friend knew. They remarked, *"I used Musée with a friend, and Ryeowook [a male solo artist] sang a ballad while I was listening to the singer-covered music [left plate]. Hearing that, my friend told me that other singers had also covered the music, and he talked more about it. We also searched for the original music itself of the music covered by various artists.*

Prior research has commonly reported that the frequency of users' exposure to music makes it more familiar, causing both positive and negative effects (Schellenberg *et al.*, 2008; Gannett, 2018). People prefer familiar music, but once this music becomes overly familiar, users' preference for it decreases (often expressed as *over-consumed* or *tired of*). Our findings showed the potential for introducing unfamiliar elements into music that has been over-consumed. In this aspect, the variety of derivative music (cover songs) provided by Musée helps the participants feel the slightly different feelings that come from various altered musical factors (e.g. unique interpretations, different voices and various musical instruments) in cover music. Consequently, by facilitating user interpretation of this slightly different feeling, Musée could offer the participants a new way of understanding cover versions of music, allowing them to imbue over-consumed music with freshness and listen in a more curiosity-inducing and positive light.

Furthermore, we were able to identify some musical factors that delivered unfamiliar feelings; user preference for the cover songs depended on how much unfamiliarity came from these factors. From this, we implied the significance of balancing familiar and unfamiliar feelings in new songs provided by our design intervention. First, there were three factors that made the music feel different from well-known music to participants: (i) *reduced musical element:* the subtraction of certain musical elements (e.g. lyrics, vocals and instruments) to make an instrumental recording, or the reduction of scales and chords to leave only melodies; (ii) *addition of peripheral noise:* inclusion of peripheral noise (e.g. sounds of cheering crowds and voice of MCs), such as a clip of a live concert or TV broadcast version; and (iii) *change in musical elements:* modifications to musical elements such as chord progressions, scale changes, lyrics and voice.

Second, we confirmed that the preference for cover songs depended on how much unfamiliarity came from these factors and how this was balanced with familiar feelings. For example, the participants preferred the addition of less distracting noises, such as an MC's voice, because it did not disturb the experience of listening to their favorite artist's voice or favorite song. However, noisy sounds such as cheers from crowds were not preferred because these sounds made it hard to focus on the familiar musical elements in the cover music. P3 mentioned, *"It creates like quiet atmosphere if the clip was from radio programs which are in the quiet environment and voices of DJ are usually quiet and smooth. But clips from live concerts do not particularly help me focus on the music because there tend to be cheers and noise from the crowds."* P2 mentioned, *"Fan recordings (of live concerts) are too focused on the recorder's favorite member of the teams... so it is quite hard to use it in daily life. But some covers made by freelance creators or recordings of some broadcast programs have audio of someone saying something . . . it makes atmosphere around me feel more comfortable and natural"* Moreover, P3 stated that a slightly altered musical key that does not spoil the feel of the original song made her listen to the particular piece even more: *"Although different people cover in different ways, I thought my favorite music could be covered like this or in that way. It also made me listen more, as the music could change a lot if they changed the [musical] key slightly."* Similarly, P4 mentioned that when she listened to her favorite ballad song in a dance version altered by a YouTuber, she could not get the emotions she usually gets from the original ballad song, which caused her to dislike the cover version of music*: "When I listened to it, it is the same song, but a different person sang it and the genre is different, so I cannot feel the emotion evoked when I was listening to the original song."*

Previous studies have revealed that when people encounter familiar music, they tend to be emotionally engaged in the songs (Pereira *et al.*, 2011; Van Campenhout *et al.*, 2013; Ward *et al.*, 2014). Moreover, our findings also show the significance of a balance between user-familiar musical elements, which make the user more emotionally engaged, and unfamiliar musical elements, which help the user feel novelty and enable listening to music in curiosity-driven ways.

5.3. Focusing on sound through restrictive representation

We designed the Musée device to play songs without providing information (e.g. the artist or music title) about the currently playing music. We found this lack of information helped users infer what elements provided unfamiliar feelings in the cover music. Odom *et al.* (2020) referred to this approach as "richly minimal," and we identified a similar effect from using Musée. In line with Gaver *et al.*'s (2003) study, the restrictive characteristics of Musée stimulated curiosity about the data because participants were faced with only the sound of the music played back to them without other information. P2 noted that they focused on music since they wanted to figure out who is covering this song, *"I was like, 'I can't recall this voice.' I keep thinking about who I am listening to when I'm using Musée. I thought the cover was good and wondered about who covered this music. Like this, I'm looking deeply into the music."* In addition, the lack of additional information provided by Musée helped users avoid becoming distracted by the additional information while listening to music. In the same vein, P3 mentioned that they focused on listening to cover music from Musée because they did not know the song's title or other information that might interfere with the listening experience. They remarked, "*(Since I don't know what the title of this song is) I feel like I'm more focused on the music itself. There is no distraction, unlike video. So, I could focus on the music itself."*

Elsden *et al.*'s (2016a) research stressed that people could experience their past data differently based on the way it was represented, which could produce valuable alternative perspectives on their sense of self. Musée provided users' past music-listening data in the form of cover versions of songs, which conveyed certain unfamiliar feelings to users, creating new music-listening experiences. As we noted in the previous section, the users tended to infer information about unfamiliar elements in the cover music they were hearing. This inferring process was augmented because only the audio was played without other information, making users focus on the sound of music.

6. DISCUSSION AND IMPLICATIONS

The findings from our work helped us explore and support the idea of users encountering both unfamiliar and familiar musical elements in derivative music—the cover version of songs. More specifically, in line with a previous study (Poirier and Pringle, 2012), by providing cover songs with both familiar and unfamiliar musical elements, we found that the participants were able to interpret music that they had considered familiar in a new light. This value was produced not by simply revisiting familiar content but by defamiliarizing (Bell *et al.*, 2005; Leong *et al.*, 2011) the users' existing log data to different forms of media (e.g. derivative music) in other channels or services. Next, we discuss the design implications of creating physical user interfaces that show users' personal data based on their digital footprint and other potential areas to which Musée might be meaningfully applied.

6.1. Unfamiliarity in music as a controllable variable

Various ways of catalyzing user interpretation of personal data through defamiliarized digital information have been studied within HCI (e.g. Leong *et al.*, 2011; Wakkary *et al.*, 2017). Building on this prior research, we explored the daily encounter of cover music, which included both user-familiar and unfamiliar musical elements through the use of digital music-listening history data and the YouTube platform. Our study showed that unfamiliar musical elements provided by a second creation (e.g. different voices, instrumentals and musical keys) could defamiliarize digital content and, in this way, lead to new kinds of music listening experiences.

In addition, when users access past content in a modified form, the data can be used by other channels (e.g. Melon and YouTube) in various forms (e.g. derived, coherent or hints) to make connections with existing data. This approach could add to users' existing digital content by providing slightly different music, with user-familiar and unfamiliar elements in each song. As previous studies noted, re-encountering previously consumed data—which feels familiar to users due to frequent access—helps users recall past experiences (Chen *et al.*, 2019; Odom *et al.*, 2019), creates meaningful interactions and provides chances for existing data to be reinterpreted and consumed in new ways (Liang, 2012). Moreover, our study showed that the unfamiliar elements—changes or modifications to the music—could be used to refresh the over-familiar content and to infer new elements.

These findings suggest new design opportunities to control the degree of unfamiliarity in the digital media derived from users' listening history data. In particular, users' listening experience could differ based on the number of unfamiliar elements (e.g. twisted musical element in cover music) or the unfamiliar elements' intensity (e.g. different instruments or several musical key changes) in the digital media. This suggests the possibility of future personal data representing artifacts that control the intensity of tension between familiarity and unfamiliarity in music and change how users encounter and perceive music from their listening history (Elsden *et al.*, 2016b).

6.2. Trade-off between curiosity and discovery opportunities

The HCI and design communities have long explored attempts to constrain the frequency of information offered (Kim *et al.*, 2019) or abstract the information (Gaver *et al.*, 2003; Lee *et al.*, 2017) presented to users. In addition, Selby and Kirk (2015) reveal that restricting explicit information about past events could induce participants to reconstruct their memories. Similarly, the curiosity derived from this restriction could cause self-directed exploration to resolve curiosity (Lee, 2016). During the field study, we found that limiting the information provided by the Musée system might stimulate more curiosity surrounding the music that came in the form of covered songs and prompt the user's curious resolving process by focusing on the details (e.g. melody and voice) of the content. At the same time, Musée's feature of limiting the information sometimes made it difficult for users to find the information they desired (e.g. the artist covering favorite song or the song title of a cover by favorite artist), leaving them wondering about twisted musical elements in cover music. These findings suggest design opportunities for creating alternative ways to represent personal data, specifically by slowly changing the amount of information available to the user at a given time. For example, devices could be designed that do not initially provide information (e.g. the title, artist or time of hearing) to the user but gradually expand the amount of detail provided over time. Previous studies (Tieben *et al.*, 2011; Kaninsky *et al.*, 2018) have suggested that this design strategy of gradually introducing information could induce users to engage in an inferring process to discover unknown information following an encounter with past data. Moreover, this longer, ongoing temporal process provides users with the opportunity to not only focus on the music and discover the unknown musical elements in cover music (e.g. artist name and song title) by inferring the additional information as hints, rather than simply remaining in a curious stage. In addition, it implied that initial restriction could lead to new curious, ludic and interpretive experiences. This might result in a deeper understanding of the unfamiliar information contained in the specific music, such as changes in the tone and genre of the artist or a different emotional response to the music. There is an opportunity for future research to investigate how such perceptions of music can be used to further engage users in exploring new areas of music suggested by past user data.

6.3. Rich data stamps for unexpected metadata use

The development and field trial of Musée showed the potential value of providing defamiliarized content [originated from the term "defamiliarization" proposed by Bell *et al.* (2005), making strange for opening new design space of domestic technologies for critical reflection based on historical digital music-streaming data.

We also identified that the use of past data to provide defamiliarized music contents depends on what metadata the certain platform contains. We found an opportunity for our research to support unexpected discovery by linking users' metadata with other types of data that are not directly related to content (e.g. original music vs. cover music) but are related to users' everyday activity data regarding time, method or location of content consumption. For example, suggestions of new possibilities could be derived not only from music-relevant metadata such as music title, artist and time of day but also from other kinds of contextual details (e.g. listening location, transportation used during listening or weather). As previous research has suggested, revisiting previously heard music (Odom *et al.*, 2019) or photos taken in the past (Chen *et al.*, 2019) in original form could evoke narrative and contextual-based impressions from past experiences, helping a user retrieve the memory. André *et al.* (2009) research team mentioned that for the valuable chance of an encounter, it is important to synthesize encountered information into new insight. For providing new insight from one's past history data, we saw new design opportunities to provide data that was contextually similar (e.g. music and social media post, which were listened to and posted at similar times, photos and music taken and listened at nearby locations) to users' previously consumed (or created) data by incorporating other services (e.g. social media service) that utilize richly a stamped digital footprint including contextual information (e.g. time or location). Providing users' most-played music and social media posts that were posted when the user was listening to the music could induce the user to think about similar contexts. It could enable the user to connect with their past deeper than by just listening to past music. Moreover, it could provide unexpected recursive use based on the metadata from social media (e.g. the messages and photos of the post, comment, and social relationship). Such encounters could provide a new dimension of data use, expanding the experience from reminiscence to a sense of connectedness. It might also be used as a conversation starter by highlighting a past social relationship contained in the comment.

7. LIMITATIONS AND FUTURE WORK

Before concluding, we would like to mention some limitations of this research and provide suggestions for future studies. First, the selection criterion for cover music on YouTube was the most-viewed content. This might have restricted the derivative music included in music by popular creators. A more diverse range of derivative music would allow users to browse music based on their selection after the initial music is shown, which might trigger new discoveries. Second, Musée's music domain is limited by its connection with YouTube, which is only one of many music-related service platforms. In the future, we will explore the value of connecting to metadata through other services as well as other music platforms.

Third, all participants were people who had listened to Melon for numerous years and could supply an extensive music-listening history data archive. As our study's focus was to explore new derivative music-listening experiences that could be generated from users' music-listening history data, we had to select people with a long history of using digital streaming services. Thus, the findings cannot be generalized to people who do not have a long listening history archived in their account; however, we believe this is worth exploring with people who have shorter records of use and how derivative music identified via their histories could affect new music-listening experiences.

Finally, we recognize the trade-off between encouraging concentration by providing limited information and stimulating curiosity and opportunities for new discoveries. More specifically, future research comparing these two perspectives will allow us to explore how we can exploit the curiosity that arises from limited information.

8. CONCLUSION

We introduced a tangible music player (Musée), a system that analyzes users' music-listening history and augments it by playing back (i) the same songs performed as covers by different amateur or professional artists or (ii) covers of other artists' songs performed by users' favorite artists. To investigate the experience of this design intervention in real-life environments, we deployed Musée in four households for 1 month. Our findings showed that Musée evoked subtle different feelings in users, supporting the re-conceptualization of songs they had liked and frequently listened to in the past. Additionally, we confirmed three factors in cover music that made songs feel unfamiliar and provided freshness to over-consumed music. Moreover, providing only the sound of the cover music helped users focus on listening to the music, which triggered a process of inference about the unfamiliar musical elements in the cover songs. Our findings suggest new research and design spaces for physical user interfaces that use digital footprints to show the user's personal data in more reflective, discovery-driven and ludic ways. Moreover, our approach and results offer the potential to expand users' digital history data by connecting it with other platforms to revisit data, make new discoveries, and promote reflection. Exploiting these new possibilities might require deeper consideration to determine how to control the degree of unfamiliarity in new information presented to users based on their past data and how much information should be provided to encourage users to engage in an inferring process and to discover unfamiliar elements.

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SUPPLEMENTARY MATERIAL

Supplementary data is available at *Interacting with Computers* online.

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