Remembering through Sound: Co-creating Sound-based Mementos with People with Blindness

Minyoung Yoo*
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
minyoung_yoo@sfu.ca

William Odom
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
wodom@sfu.ca

Arne Berger
Computer Science and Languages, Anhalt University of Applied Sciences, Koethen, Germany
Arne.Berger@hs-anhalt.de

Sam Barnett
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
sam_barnett@sfu.ca

Sadhbh Kenny
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
sadhbh_kenny@sfu.ca

Priscilla Lo
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
priscilla_lo@sfu.ca

Samein Shamsher
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
samein_shamsher@sfu.ca

Gillian Russell
School of Interactive Arts and Technology, Simon Fraser University, Surrey, Canada
gillianr@sfu.ca

Lauren Knight
Faculty of Information, University of Toronto, Toronto, Canada
lauren.knight@mail.utoronto.ca

Figure 1: Co-design workshop session with participants

ABSTRACT

Sound is a preferred and dominant medium that people with blindness use to capture, share and reflect on meaningful moments in their lives. Within the timeframe of 12 months, we worked with seven people with blindness and two of their sighted loved ones to engage in a multi-stage co-creative design process involving multiple steps building toward the final co-design workshop. We report three types of sonic mementos, designed together with the participants, that Encapsulate, Augment and Re-imagine personal audio recordings into more interesting and meaningful sonic memories. Building on these sonic mementos, we critically reflect and describe insights into designing sound that supports personal and social experiences of reminiscence for people with blindness through sound. We propose design opportunities to promote collective remembering between people with blindness and their sighted loved ones and design recommendations for remembering through sound.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Interaction design.

KEYWORDS

Reminiscence, Co-design, People with Blindness, Sound, Sonic memory, Research through Design, Co-creation

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1 INTRODUCTION

Long before the advent of writing, many ancient cultures relied on oral traditions to pass down their histories, myths, legends, and stories [26]. These oral traditions often involved the use of spoken words, songs, and ritual chants to deliver or preserve important information and narratives, making and preserving memories through sound, and connecting people more intimately with the natural world [33, 71]. The sounds of wildlife, flowing rivers, and rustling leaves were integral to their daily lives. These natural soundscapes provided practical information and left lasting impressions, contributing to people's personal and cultural memories.

Later, the invention of sound recording technology in the late 19th century revolutionized how people made memories with sound. For example, Thomas Edison's phonograph and subsequent developments allowed individuals to capture and reproduce sounds, including voices and music [72]. The advancement of digital technology has enabled individuals to create, store, and share sound memories like never before. Voice messages, sound recordings, and music playlists have become modern forms of sonic memory. In the Human-Computer Interaction (HCI) and design community, there is a growing body of research exploring people's experiences with sonic memories (e.g., [25, 44, 45, 61, 66, 69]) to capture, revisit and share their memorable life experiences with significant others. However, ironically, these initiatives primarily focus on the sighted population. Although blindness is an actively researched topic in the HCI community, the majority of research has focused on overcoming practical challenges, such as navigation (e.g., [3, 32, 48]), screen readers (e.g., [9, 15]) and usability of digital services (e.g., [1, 4, 12]). How audio might be explored as a material that could enrich other vital aspects of the lives of people with blindness, such as reflection, social connection, and reminiscence, has been overlooked [96].

Before this background, we ask: How do people with blindness capture, revisit and share their cherished audio recordings with loved ones? What are the important qualities that make audio recordings meaningful for people with blindness? What are the preferences, desires, challenges and limitations in interacting with personal audio recordings for reminiscence? How can we design together with people with blindness to support them in creating meaningful memories in sound in a way they prefer to possess and enjoy? How can we translate their personal audio recordings into alternative types of sound memories to promote personal and social reminiscence?

Drawing on Research through Design [35, 97, 98] and co-design [8, 77] approaches, our research investigates these questions by designing sound memories together with people with blindness. As a continuation of our research project on designing for the reminiscence experience of people with blindness [95, 96], we report on a 12-month co-creative design process, where we took a series of careful and respectful steps to work closely with participants, building towards an in-depth co-design workshop, where we translated cherished audio recordings owned by our participants into alternative forms of sonic memories. We discuss three sonic mementos in detail and present three design opportunities: (i) *Encapsulation and Condensation*, (ii) *Augmentation and Expansion*, and (iii) *Re-creation and Re-imagination*. Further, our discussion articulates insights into the nascent and emerging design space of remembering through sound. We describe three design strategies to promote collective remembering in sound and three design recommendations to support better remembering through sound for future research and practice. This paper makes two contributions. First, we offer three types of sonic mementos as novel design opportunities that can extend beyond personal audio recordings cherished by people with blindness. Second, we propose recommendations on the design space of sound and sonic mementos for supporting personal reminiscence and collective remembering through sound in future HCI research and practice.

*Corresponding author

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2 RELATED WORKS

2.1 Designing for Remembering and Reminiscence

Remembering is the cognitive process of bringing past knowledge, events, or experiences from one's memory to present awareness. Yet, as Tulving described [27, 86], some memories—categorized as "episodic memories"—are oriented towards recalling specific events and experiences rather than general knowledge and facts about the world. Thinking and talking about our past relies on autobiographical or social remembering. This is an essential practice for people to promote positive self-reflection, construct ideas of one's future self, or maintain social bonds [7, 13]. Butler introduced the concept of "life review" [14]—a process in which people reflect on their life and past events, experiences and memories. Life review has been further developed in relation to the concept of reminiscence, a deliberate and positive process of recalling and sharing memories from their personal possessions and stories (e.g., [53, 60]), often in an emotional and nostalgic tone.

In the HCI and design communities, remembering and reminiscence are essential to understanding and designing technologies that involve meaningful possessions, memories and personal experiences [36, 42, 43]. Recently, there has been a growing interest in understanding interactions and experiences with digital archives as growing digital repositories have created new ways of remembering people's past life experiences [29, 42, 64]. A wide range of digital archives, such as social media, music listening history, sound recordings, and digital photo archives (e.g., [10, 19, 25, 51, 65, 83]), have been explored to offer unique experiences for people to re-live their moments from the past.

Despite reminiscence being an essential part of everyone's lives that defines us uniquely as humans [21, 87], there is limited research on the experience of reminiscence and remembering for people with blindness. Previously, we conducted an exploratory study investigating how people with blindness capture meaningful moments and reminisce on past life experiences [96]. Findings from this work provided foundational insights into three design opportunities for supporting the reminiscence experience of people with blindness: (i) *reminiscence through sound* (e.g., audio recordings, voices, soundscape), (ii) *reminiscence through social interaction* (e,g., other people's visual descriptions, storytelling, social gathering), and (iii) *reminiscence through tactile impressions* (e.g., physical presence and tangible aesthetics). We build on our prior research by focusing on reminiscence through sound, as it was the most preferred and commonly used medium among the three opportunities, informed by the participants. We extend our previous work through a hands-on, generative approach to gain an in-depth understanding of the reminiscence experience through sound for people with blindness and to explore new design opportunities for creating sonic memories with their cherished audio recordings.

2.2 Sound Memories, Sonic Memories

Sound, as an integral part of human experience, has a unique capacity to trigger emotions, bringing people back in time and rekindling the essence of memorable moments, influencing how people perceive and interact with their surroundings [58, 84]. While the study of sound memories is interdisciplinary, bridging psychology, cognitive science, and sensory studies in the fields of design and HCI, understanding how people engage with sound memories has become increasingly important due to its potential implications for designing technologies for open-ended experiences, such as reflection, introspection, and recollection. This is particularly evident in relation to memory and remembering, where auditory cues hold a distinct power in evoking the emotions of past moments to recreate memories [61, 69]. In this vein, sound memories, or 'sonic memories', encompass the capacity of sound to trigger personal reminiscence and emotional responses [25, 66]. These cues can include spoken words and ambient sounds, music, and other acoustic elements that contribute to the richness of personal memories (e.g., [20, 50, 51, 61]). For example, Oleksik and Brown highlight that sound memories are "omnidirectional" as information comes from all directions and are more immersive when captured as opposed to "unidirectional" visual memories, where the person must be behind the camera, constantly paying attention [66]. This body of work offers a novel perspective on the ways people reconstruct and relive their past experiences through sound.

However, sonic memories introduce unique challenges and opportunities for technology-mediated reminiscence, especially in the design of interactive systems and digital archives, as people's intentions regarding sound recordings and their preferences to organize or share such recordings are largely underexplored. Oleksik and Brown [66] report a significant challenge in maintaining sound archives because there is no "thumbnail" of sound. Therefore, although sound could be more evocative than visual memories, listening to "unaccompanied audio" that provides a little "frame of reference" can result in a lessened impression of listening to sound memories for people who are not involved in the original scene. Further, the authors point out that giving a proper form factor to sound is a major design challenge. Petrelli et al. describe similar concerns [69] regarding the absence of "prominent feedback" when navigating sound files. This leads to "tedious" tasks of organizing, labelling and time-consuming editing. Hsieh et al. [44] agree with the limited control in selecting desired sounds for playback. While the authors leverage this limitation as a design concept to evoke serendipitous experiences, having a lack of control while browsing sounds still remains a design challenge.

Collectively, these insights and challenges make clear design initiatives aimed at sound memories with a comprehensive understanding of how people perceive, recollect, and engage with auditory cues. However, this stream of research has almost entirely focused on the sighted population. Currently, there exists very limited prior research that specifically investigates the experience of reminiscence for people with blindness. As our previous findings point out, sound serves as one of the prominent design opportunities for the practice of remembering and reminiscing for people with blindness [96]. Yet, this research direction has not been actively researched in the HCI and design communities. While how sighted people utilize various sounds to capture and remember meaningful moments resonates with that of people with blindness (e.g., personal audio recordings of soundscape, conversations and voices), designing sonic memories from the perspective of people with blindness requires more attention. Therefore, our research aims to explore further opportunities in the context of sound for

people with blindness and how they remember, revisit and share memorable experiences in their lives. We aim to take a collaborative approach, working closely with participants, as it contributes to the design space of technology that is more inclusive, meaningful, and emotionally resonant with people with blindness.

2.3 Designing Together: Co-design with People with Blindness

Designing future technology, together with those that will be affected by it, has proven to balance power distances between designers and co-designers [81]. Sanders and Stappers describe this shift in design as "designing of" products to "designing for" a purpose [77]. The co-design approach reframes 'users' as *co-designers* who actively collaborate in knowledge creation. Co-design offers the potential for generating novel, often idiosyncratic, design outcomes that are better aligned with the lives, worlds, values, needs, and desires of involved parties [5]. Yet, co-designing with marginalized communities presents complex challenges to reducing power imbalances and supporting creative capacity [40, 46]. Thus, participants must be positioned as experts of their own lived experience, while facilitators (researchers and designers) utilize their expertise to support participants in leading the design [77]. This approach has been widely adopted in the HCI and design communities to work together with various sensitive populations, including but not limited to people on the autism spectrum, deaf people, older adults, and children (e.g., [34, 74, 79, 90, 92, 93]).

Co-design workshops often involve highly visual tools such as worksheets and low-fi paper prototypes to guide the design process, sketch out ideas, and generate shared understanding. However, researchers have developed alternative methods of non-visual tools and activities to work better with blind and visually impaired participants. Such non-visual methods include but are not limited to: envisioning new technology with scenario-based voice role-playing and tactile artifact-building sessions [11]; using design probe wearable objects for exploring interactions [31, 88]; exploring interactions with 3D-printed objects [54] and sound samples [23, 55]; and developing sound prototypes with everyday objects, such as balloons, sticks and walls [91].

There is a growing need for non-visual methods and activities that can empower participants with blindness as the landscape of accessible co-design develops. Prior works demonstrate how critical attention to the needs of blind people can enable more meaningful and engaging participation [6, 57]. Yet, striking a balance between accessibility and autonomy in the design activities and methods *for* people with blindness can pose a significant challenge throughout the design process. To date, no co-design workshops have been held at the intersection of the experience of reminiscence for people with blindness and the roles of sound. Therefore, we chose to work closely with participants, positioning them as active co-designers through continuous engagement and exchanging feedback as we developed insights into the design sessions and interactive activities. Our work contributes to this stream of research by reporting our design journey from ideation to developing the co-design workshop with people with blindness from the ground up.

3 PROJECT BACKGROUND

3.1 Methodological Approach

Our methodological approach draws from a blend of Research through Design [35, 97, 98] and co-design [8, 76, 77] methods. We aim to establish a collaborative design approach that offers our participants an equitable and engaging decision-making process and respects the principles of inclusivity and reciprocity. This research directly builds on and extends our prior work [96] that describes design opportunities for reminiscence experiences for people with blindness. We aim to address the challenge of designing an inclusive and wholesome co-creative design process for and with people with blindness from the bottom. Our research team engaged in a 12-month co-creative design process in three phases: (i) *Understanding*, (ii) *Exploring* and (iii) *Co-designing*. Each preliminary phase provided important touchpoints that built up to the final co-design workshop in the last phase.

In our view, it is important to account for our design journey, which is similar to the "research journey" [82]. The three phases were not initially developed before the recruitment. Rather, we decided to take a series of small steps, working our way with the participants. As we concluded each phase, we paused to reflect on what we had documented, then checked in with the participants to review the insights drawn from each phase together. This step enabled us to confirm if we correctly interpreted our participants' voices. Further, such continuous collaboration revealed multiple "design research events" [68] that shaped the next steps.

Our design journey is less about the summative outcomes and more about reporting multiple touchpoints and meaningful reflections and outcomes that guided us to more in-depth insights that finally led to the co-design workshop, which is the majority of what we report in this paper. The co-design workshop aims to draw on personal audio recordings and sonically significant physical objects owned by people with blindness to explore sonic interventions that enrich the reminiscence experience through sound. Overall, our goal is to build on the "feelings, dreams and imaginations" [28] of people with blindness by inquiring into their first-hand, situated and lived knowledge. However, because we ourselves are not blind and have never experienced the life of people with blindness, we planned to be involved in a direct collaboration to address challenges together.

3.2 Our Positionality

The research team consisted of three leading researchers, five design researchers and one sound researcher, none of whom are blind or experience severe vision impairment. Thus, it is important to acknowledge our positionality.

- MinYoung Yoo has five years of experience collaborating with people with blindness for design-oriented research projects and was involved in volunteer work at a local institution for the blind for one year.
- William Odom has prior experience with a non-profit social program that paired younger adults with older adults living with vision impairment, which aimed to support intergenerational socialization and dialogue; they also have several

years of experience collaborating with people with blindness for participatory research projects.
- Arne Berger has completed 1 year of community service volunteer work in a school for blind and visually impaired students and, more broadly, has 6 years of experience in co-designing with people from different walks of life and abilities.
- Lauren Knight has prior experience on a design-oriented research project that collaborated with people living with vision impairment. Within this project, she contributed to understanding a sound-related worldview and developing discussion topics and questionnaires that informed workshop activities.

The following five authors contribute to analyzing collected data, designing co-design workshop activities and hosting the workshop as facilitators.

- Sam Barnett has expertise in video and sound production, as well as experience in facilitating workshops and engaging in conversations with youth.
- Sadhbh Kenny has prior experience in facilitating co-design workshops with vulnerable youth populations and working with those with differing developmental abilities.
- Priscilla Lo comes from a background focused on designing and developing interactive multimedia. Recently, she has been involved with non-profit organizations supporting children and youth with visual impairments.
- Samein Shamsher has experience in devising techniques for co-speculation with the public and has worked in a political capacity to advocate for marginalized and vulnerable groups.
- Gillian Russell brings years of experience in developing methods and tools for co-creation and co-speculation; she also has experience co-designing *with* vulnerable populations in various academic and industry contexts.

These lived experiences have provided our research team with sensitizing insights into the lives of people living with blindness. However, we ourselves cannot experience what it is like to live with vision impairment or blindness, and this is an important limitation to acknowledge. This pivotal point informed how we conducted this research project with sensitivity and care. With the aim of foregrounding the voices, desires, and values of our participants, we explored new design possibilities that could positively shape the lives of people living with blindness.

3.3 Participants and Recruitment

We first contacted participants from the previous study to inquire if they were interested in continuing their involvement in this research. Thankfully, four participants expressed keen interest in participating in the subsequent phases of the research. Then, more participants were recruited through word-of-mouth referrals, as continuing participants introduced us to their friends, significant others and members of their communities. We initially recruited 8 participants, but one participant had to withdraw, leaving a total of 7 participants (3 males and 4 females). We refer to each participant with a pseudonym:

- **Ray** (early 40s) is totally blind and runs a podcast series that shares the life experiences of people with blindness. He also works as an interpersonal relationship counsellor and a self-defence Krav Maga instructor.
- **Luni** (early 40s) was born with low vision and became blind in her early 30s. She is a certified massage therapist who has short-term memory loss but finds her own way to live her life with joy.
- **Carol** (early 70s) was born blind. She studied music and education and worked for over 20 years as a braille proofreader and then as a word processor.
- **Janet** (early 70s) is totally blind. She is a retired teacher of students with visual impairment who enjoys travelling and doing volunteer work.
- **Hana** (late 50s) lost her sight in her early 20s. She moved to Canada as an international student, where she met her husband **Walter** and had a son. She currently works at a pitch-black restaurant that simulates the experience of blindness for customers.
- **Walter** (early 60s), Hana's husband, was born visually impaired and began losing his remaining sight in his 40s. Walter is a former soldier and drummer who has developed his identity through martial arts.
- **Alan** (early 30s) has been blind since birth. He worked at an international student agency where he taught English, was a counsellor, and showed international students around the city. Alan is interested in blindness advocacy, such as participating in research studies and engaging in public safety and policy-making.

For the final co-design workshop, we invited participants' important others to the workshop to work in pairs. 4 among 7 participants—**Ray**, **Janet**, **Hana** and **Walter**—joined the workshop with 2 sighted partners:

- **Scott** (early 80s) is Janet's sighted husband. He exhibits a great sense of humour and enjoys helping others.
- **Michael** (early 50s) is Ray's sighted friend. He is married with two kids and is a retired financial advisor, hockey player and martial artist.

3.4 Documenting and Shaping Our Design Journey

Over the course of 12 months, we employed a range of techniques to conduct and document our participatory design process, which began with *Introductory group interviews* for Understanding (phase 1), continued into *Participatory field activities* for Exploring (phase 2), and concluded with a summative *co-design workshop* for Co-designing (phase 3). Importantly, in this paper, we emphasize outcomes produced during the co-design workshop. However, we also summarize the preceding phases that led up to the workshop and provide context for it. Thus, we offer a sequential synthesis of design research events [68] throughout our design journey, leading up to the co-design workshop.

All sessions involving the participants across the three phases were audio-recorded using two distinct methods. First, lavalier microphones (Zoom F2) were used to capture condensed sounds, such as conversations, verbal descriptions and impressions (Phase 2). Then, handheld audio recorders (Zoom H4N) are used for field activities to capture the soundscapes and atmospheres (Phase 2)

and the overall discussion during group interviews (Phase 1) and the co-design workshop (Phase 3). We also took photographs and video clips to document the scenes visually. Field notes describe the reflective thoughts from the researcher's perspective and capture participants' comments made during each interview and design activity session. Each session ended with a concluding discussion as we shared immediate reflections from the field notes, asked for participants' thoughts and impressions, and brainstormed the next steps. Then, the research team organized tentative insights and ideas into reflective field memos [37]. At the end of each phase, the field memos, along with weekly project meeting notes, audio recordings, videos and photos, were repeatedly analyzed to develop affinity diagrams to draw emergent patterns and themes as an ongoing process [22, 59].

4 COLLABORATIVE DESIGN PROCESS

Next, we report and reflect on each phase of our design journey to illustrate our pathway toward the final co-design workshop. We emphasize our design journey to focus on the "through" part of Research *through* Design [24]. We dedicated these steps to conducting formative research aimed at understanding our participants' needs, desires, and challenges while also maintaining ongoing engagement with them over time.

4.1 Phase 1: Understanding – From Audio Documentary to Introductory Group Interviews

The beginning of our collaborative design journey was dedicated to fostering connection and mutual understanding among the team and participants to facilitate engagement over time. We were cautious not to pre-determine the final design outcome; instead, we sought to explore our participants' potential collaborative interests. Thus, the first phase focused on developing a shared understanding of the main concepts of this research, such as *audio memory*, *audio portraits* and *audio highlights*. The first phase included two key components: the audio documentary and introductory group interviews.

4.1.1 Methodological Approach. After the initial phone screening, participants were invited to partake in an individual, self-paced engagement with an hour-long ***audio documentary*** [95]. The audio documentary was originally created as an alternative research outcome [94] that could be delivered back to the blind community in a more accessible, immersive, and appropriate form. We leveraged this audio documentary to initiate a thoughtful dialogue for our blind participants and the blind community that we have been engaging with over the past 4 years. The audio documentary helped our participants understand the context of reminiscence experience and sound memories. **Janet** and **Hana** later shared that the audio documentary invited them to reflect on their perspective of making and revisiting memories through sound. Then, we conducted ***introductory group interviews*** (Figure 2) centred on sound to establish rapport, gain insights into the participants' perspectives and inform the design of the final co-design workshop in the later stage. We hosted three group interviews separately. Groups were organized based on existing relationships among participants to make them feel more connected and comfortable when sharing their personal stories. Discussions during these sessions first delved into their existing practices, future desires, and challenges around making and interacting with memories in sound. The second part extended to how people with blindness understand and perceive sound, their everyday experiences in relation to sound, and how they envision to capture and revisit memories through sound.

4.1.2 Key Takeaways. The insights gathered from the introductory group interviews revealed intriguing nuances. Despite sound being a desired and preferred medium for capturing memories, participants possessed a limited number of meaningful recordings and rarely listened to them. However, across all participants, it was clear these recordings held great personal significance and were reported to be among their most cherished things. Participants expressed a strong desire to capture the moment while creating memories through sound. They also noted that such valuable moments—our participants named these meaningful moments as ***sonic highlights***—often happen so fast that they can be quickly forgotten. This underscores the practical difficulty in sonically capturing significant moments. A common workaround was to leave a sound recorder running during special occasions. However, this approach raised additional challenges making it difficult to pinpoint and share meaningful moments within lengthy audio recordings. The need to avoid large recordings also introduced another limitation: it was difficult for participants to have the foresight to 'know' when a memorable moment was going to occur. Thus, these constraints made the experience of capturing impromptu *sonic highlights* in audio extremely difficult. During our collective discussions, **Walter** and **Alan** suggested that it would be interesting to develop a concept that could emulate how *sonic highlights* could be captured on the scene.

4.2 Phase 2: Exploring – Participatory Field Activities

In Phase 2, our focus shifted to fostering more hands-on, interactive activities with our participants. We consider this phase to be pivotal in opening up our participants' lived experiences and creative capacities; it allowed us to scaffold the outcomes of these activities to empower participants to take the lead in the design process.

4.2.1 Methodological Approach. To continue investigating how participants might desire to collect *sonic highlights* of live experiences, we invited participants to choose an activity or event they would enjoy participating in groups. Our research team drew inspiration from "go-along" interviews [16] involving shadowing and observation to develop a lightweight participatory field activity that would capture *near-past* moments that just happened and passed. The idea was to gather "retrospective sound" [39, 67]. However, although this idea was suggested by our participants, it was still unknown whether this was actually a design direction that participants would prefer. Further, designing a working prototype to do this would take considerable development time and resources. Thus, instead, our research team acted as an imaginary device. While participants enjoyed their moments at the events they attended, the accompanying research team—equipped with sound recording devices—shadowed the participants. Participants were also wearing microphones as the research team continuously recorded the surrounding soundscape while shadowing them. The concept of

Figure 2: Introductory group interviews with participants in three groups: Janet, Ray and Luni (left), Carol (middle) and Alan, Hana and Walter (right)

Figure 3: Ray and Luni went horseback riding as their participatory field activity.

"ambient sound" that comprehensively captures the experience as a whole resonated with our participants' experiences, which appears in our prior research findings [96] and the audio documentary. This also aligns with the concept of a "soundscape" as defined by Pijanowski et al., wherein a soundscape is described as an amalgamation of "biological, geophysical and anthropogenic sounds" originating from a landscape where the collection of sounds varies across space and time, reflecting crucial ecosystem processes and human activities [70]. Likewise, our participants perceived that capturing the soundscape at the scene of a memorable event was critical to understanding the nuanced experience and emotions at key moments during it.

When participants encountered a *sonic highlight* worthy of being captured, at that precise moment, we asked them to give an auditory cue (e.g., snapping fingers or tapping their mic) as a marker in the recording. The research team later spotted the cues in the recordings and retrieved 15-20 seconds of the near-past moments around the cues to capture participants' points of interest. These *sonic highlights* were created as a set of mp3 files and shared with the participants via email for them to revisit or use however they desired.

Figure 4: Hana, Walter and Alan took the Swordplay 101

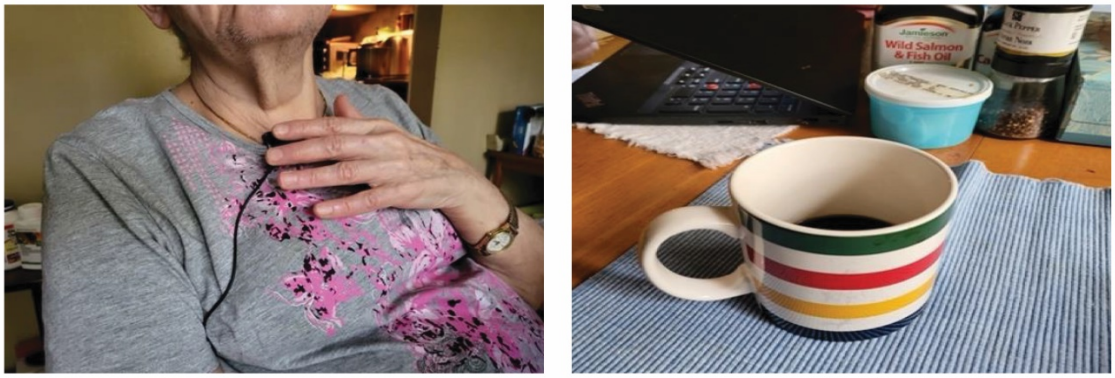

Figure 5: Carol enjoyed a coffee chat in the quiet early morning with a series of small laughter.

When choosing an activity, we encouraged participants to explore a wide array of options, ranging from momentous or unique events to mundane activities. They were free to choose any experience they wished to capture sonically, reflecting their personal preferences and interests. As a result, a set of activities our participants elected for the participatory field activity to make sound memories were diverse.

- **Ray** and **Luni** went horseback riding for their anniversary (Figure 3). They both had ridden a horse long ago, but not recently. During the activity, they recorded many moments of surprise and excitement, such as when they first met the horses and proceeded to go horseback riding. Later, the instructor let them pet and feed horses for their special occasion.

- **Hana**, **Walter** and **Alan** participated in an introductory swordplay session at the European Martial Arts institution (Figure 4). It was Alan and Walter who decided on the activity. Hana got curious to find out what it was about and ended up really interested in learning the theories and science behind the medieval battle.
- **Carol** invited the first author to her home for a fresh cup of coffee (Figure 5). She enjoyed making coffee in the morning and chatted for an hour. While talking about many small things, she marked a few highlights, such as her favourite sports, childhood dreams, impressions and experiences on the research.
- **Janet** wanted to make sonic highlights of walking with her granddaughter, Christina, and a guide dog, Sam (Figure 6). It was her daily routine, but because spending time with Christina was so special to Janet, she felt inclined to make audio memories of them going for a walk.

Later, we shared the sonic highlights with the participants and followed up with them by phone calls and descriptive email replies. Participants were impressed by how other sounds that they could not notice in the scene were captured so clearly, giving them an alternative view of reviewing their experience. For example, **Ray** was surprised how he was able to hear the horse's footsteps in the highlights that he had never noticed or paid attention to for the whole time. Similarly, **Hana** liked the soft clinking sounds of gauntlets that brought the feelings of touching and wearing them. **Alan** commented that he would choose highlights of *"special sounds"* and *"unique moments"*, such as the unique metallic sound of a round shield blocking a long sword, over recording information about medieval history that he could easily find on YouTube. Participants commented that having the sonic highlights made them ponder, *"What is the meaning of having access to the highlights of an event?" "What do I wish to do with these highlights?"*

4.2.2 Key Takeaways. The participatory field activities gave us a major insight into uncovering specific attributes that our participants valued in their audio memories. These activities also served to prime them with sonic highlights in preparation for the upcoming co-design workshop. While we found the initial concept of capturing sonic highlights from the previous phase was highly desired as an aspirational concept, it did not work as expected in practice for two reasons.

First, we discovered that a 'less demanding' interaction was crucial for effectively capturing audio memories during special events. Capturing the sonic highlights with a simple cue was enjoyable and intuitive, but some participants were so absorbed in the moment that they forgot to provide cues to mark the highlights. Our research team was able to find a workaround by 'cherry-picking' highlights on behalf of the participants. Given our close observation and indirect involvement in the scenes, we could anticipate when participants might find the experience intriguing. We later reviewed the chosen sonic highlights with the participants, and they were pleased that we were able to identify the highlights that emotionally resonated with their own impressions. However, all participants agreed that even a simple conscious interaction was too obtrusive, could disrupt the experience, and was ultimately unwanted.

The second challenge emerged when we checked in a month after sharing the sonic highlights. Although the participants appreciated the sonic highlights and kept them, most of them eventually lost track of their whereabouts among other digital files, complicating their accessibility as a valuable resource for reminiscence. Thus, instead of capturing and creating new sonic memories, our focus shifted towards working with the original sonic memories that participants had repeatedly mentioned. We aimed to design for the unique experience of remembering that unfolds through the existing sound recordings.

These insights played a significant role in shaping our design direction and served as resources for designing the sound-based activities. It is important to note that the intention behind this approach was not to evaluate the participatory field activity method itself, but instead, we sought to understand the participants' experience with having such an imaginary device for capturing audio memories and to explore potential design opportunities with the sonic highlights. In summary, conducting the participatory group activities was rooted in our commitment to continuous engagement

Figure 6: Janet made audio memories from her mundane routine of walking with her granddaughter, Christina.

to understand participants' worldviews and to translate their stories, ideas, personal experiences and desires into actionable design elements that ensured their voices and perspectives were core to guiding our process.

4.3 Phase 3: Co-designing – Develop and Host the Co-design Workshop

Our research team reviewed all insights from the introductory group interviews, sonic highlights obtained from the participatory field activities, and participants' reflections on the sonic highlights to develop the final co-design workshop. Finally, we came up with three activities inspired by the approaches of storytelling [2, 30, 75], co-listening [18], and co-speculating [49, 56, 89] in the context of sound. The final co-design workshop was led by four facilitators and assisted by three supporting members of the research team. The workshop lasted three hours and drew six attendees, consisting of four (**Ray**, **Janet**, **Hana** and **Walter**) of the seven participants and two attendees significant to them (**Scott** and **Michael**), resulting in three pairs. Each participant pair, a facilitator and a supporting member, formed one focus group, with the main facilitator overseeing the workshop (first author) and supervising across the three focus groups.

Activity 1: Sensitizing and Storytelling – Prior to the workshop, participants were asked to bring a cherished audio recording or a sonically meaningful object. Additionally, they were encouraged to bring a significant person from their lives, such as a friend, partner, or family member. The first activity commenced as a large-group discussion. It started with an icebreaker, providing an opportunity for both participants and facilitators to introduce themselves and share the types of sounds they loved and disliked. Then, each pair shared the sounds or objects they brought, describing the significance and the stories behind them. Facilitators guided the discussion with reflective and exploratory questions, aiming to unveil emotional and social dimensions within the audio and stories, such as: What is the theme of your memory? What are the sounds you remember the most in this scene? Are there any unexpected sounds captured in the recording? What are the other senses involved in this memory?

Activity 2: Co-listening – Each focus group moved to separate rooms, where they dived into their sounds and personal stories. The questions were designed to encourage in-depth conversations about their inspirations and aspirations for transforming their cherished audio into a desired form. Our insights from the participatory field activities (Phase 2) revealed that the sonic highlights often revolved around specific and distinct sounds. Guided by this understanding, we explored questions while closely listening to the audio together to understand how memory is reconstructed in sound and, conversely, how sound reconstructs memory. We asked: How do you feel when listening to the recording? What is the first/last sound you remember from this memory? What is the highlight of this memory? Which sound resonates with you the most in this recording? What was in the background? Is there any sound you remember but not captured in the recording?

Figure 7: Storytelling (top left and bottom right) and co-listening (top right and bottom left) sessions for activities 1 and 2.

Figure 8: Participants listening to the final sonic mementos created from the co-speculation session.

Activity 3: Co-speculating – Lastly, facilitators collaborated with participants to translate their audio and associated memories into meaningful sonic representations, following their lead. We started by prompting participants to elucidate the surroundings, atmosphere, and environment of the memory scene, such as the physical place, the emotional climate, the time of day, and the people who were present in the scene. The question "How should the memory start/close?" especially helped participants envision how their memories can be meaningfully represented by sound according to their preferences. Building on their personal audio pieces, each facilitator used sound-editing software, free online sound databases, and a microphone to record their voices and short narrations to craft sonic mementos, following our participants' guidance closely. As a result, we created three sonic mementos that are vastly different. In the following section, we provide a detailed description of three sonic mementos and the process of co-creating them together.

5 CO-DESIGN OUTCOMES – THREE TYPES OF SONIC MEMENTOS

We present three types of sonic mementos created together with the participants during the co-design workshop as case exemplars, which illustrate the outcomes of our 12-month co-design process. As textual descriptions may not fully deliver sonic qualities, we have attached three sonic mementos as supplementary materials. The original versions include *Sparring Highlight* and *Baby Bell*, while *Boat Trip* is an anonymized version where people's names mentioned in the recording are replaced with a short dip of silence.

5.1 Encapsulation and Condensation - Ray & Michael's Sparring Highlight

Ray brought a 28-minute recording of a Krav Maga session. Although neither Ray nor Michael specifically recalled the session, listening to it evoked an embodied reaction in both. As we listened to the audio together, they identified that listening to the violence of the session brought up the same rush of adrenaline and sense of danger as being in the room itself—they could feel it physically. For this reason, Ray occasionally listened to the recordings he makes of Krav Maga sessions, while Michael, though he had never re-listened to the recordings before, was moved by the experience. Ray and Michael identified the value of reliving this experience, yet they found the 28-minute recording unwieldy to navigate, unfocused, and impractically long. As our discussion unfolded, we arrived at the idea of creating a sonic highlight that prioritized the elements of the recording that triggered this embodied memory and that also included sounds that provided context, a narrative throughline, and dramatic flair. Drawing from Ray's background as a podcast creator, Ray brought valuable insights into sound editing to the table. He had previously edited recordings of his Krav Maga sessions to use as the opening of his podcast. He shared his perspectives and concrete suggestions on weaving a narrative through-line that drives through the sonic highlight.

Upon listening to the sound recording again, Ray and Michael were able to pinpoint specific sounds that were iconic or indicative of recurring memorable phenomena from their Krav Maga sessions. The violent sounds of pads being hit were immediately agreed on as the core triggering sound, and thus, two clips of pad hits formed the backbone of the sonic memento. Another key sound was the instructor, whose gravitas and presence are a core component of their memories of the sessions. In the sonic memento, the instructor's voice served as punctuation and was interwoven throughout. It was often heard in the background of other clips, such as pads being punched and kicked, and contributed to the decision-making process regarding why these specific moments were chosen. We used the instructor's voice, issuing specific commands to create a framework in which the other sounds from the class could be inserted.

Tensions also emerged in the recording. A particular sound—the presence of Electronic Dance Music (EDM) playing in the background—was much more noticeable in this original recording they brought, which was different from how they remembered the usual sparring sessions. Because the loud music broke their focus, they wanted it to be removed as we created the sonic memento. When asked whether there was value in retaining the background music to be true to the authentic experience, Ray and Michael were more interested in editing the memory to their preference. The essence of their experience was the powerful energy and emotion evoked by the sounds of the sparring session, which both Ray and

Michael wished to capture and preserve. This discussion reaffirmed our shared understanding of the goal of this sonic highlight.

Sonic Narration: The sonic memento begins with the Krav Maga instructor shouting instructions and clapping at the class. This is followed by the sound of pads being hit, with occasional grunts and scuffles. The instructor's voice can be heard in the background. This is followed by a new instruction to the class, telling them *"two hits"*, and then a sound *"GO!"*. You then hear the percussive sound of elbows hitting pads. This is followed by two clips of a trainee groaning and then yelling in pain before a clip of positive encouragement from the instructor: *"Yeah, yeah, that's it!"*. The sonic memento ends with indistinct mumbling, conveying the atmosphere of the room.

5.2 Augmentation and Expansion - Janet & Scott's Boat Trip

Janet and Scott brought in several audio recordings from a trip they had taken together to an Island off the coast of Western Canada. Taking an audio recorder to eventful moments was a common practice so that they could later listen and share the experience with friends and family. Janet, especially, valued these recordings as they featured rare instances of both her and Scott's voices. The recordings ranged from two to five minutes. While these clips already served as a well-established form of sonic memories, key questions emerged: *What could be done with these recordings to enhance their characters? What could be done to the recordings to allow them to be shared more easily with friends and family?*

As Janet and Scott recounted stories beyond the recordings, it became evident that certain sounds were absent in the recording, contrasting with their memories of the event. For instance, Janet recalled a clinking metal sound from the boat's deck. Scott did not recall the clinking sound, but Janet clearly remembered it. Conversely, Scott remembered "a nice low humming sound" of the boat motor that was missing in the recording. The motor sound was probably too soft to be caught by the recorder, yet the sound was vivid in his memory. This realization prompted them to closely retrace moments, at times, adding missing sounds to enhance the sonic experience.

To evoke the atmosphere and emotions tied to the soundscape, Janet and Scott decided to add specific sounds and narrations to the sonic memento. Janet expressed a desire to add a Puffin sound—a common local seabird found around the island. In more detail, she specifically asked to gradually increase the volume of puffin sound as the boat arrived at the cliffs where puffins nested. Puffins laid eggs in the flat areas between the rocky cliffs, the tour guide explained. Near the cliff, Janet and Scott both felt the boat bouncing up and down due to strong ocean tides breaking through narrow and sharp rocks, making the sound of "the water moans the rock away". Janet noted it as the sound of the irregular and indented coastline of the Atlantic Ocean as opposed to the sound of the gently curved shoreline of the Pacific. These meticulous details were translated by catching the details of each sound component and finding the right sound—imported from the online sound libraries—and volume that best described and represented the ones in their memory. The final edit included the sounds of the boat motor, the specific calls of seabirds, the sensation of the wind, the weather, and finally, the sprays of the ocean. The contextual markers created with a complex mixture of sounds played an essential role in vividly retelling the story of their trip and giving a sense of *timing* that added another level of richness to the atmosphere.

On top of the added sound components, Janet wanted to include short narrations in the final version of the sonic memento that give hints about the information that cannot be explained solely through sound, not only the details of the trip but also their emotions and inner thoughts throughout the trip. This led to a further dialogue of when the memories 'start' and 'end' as well as the key highlights throughout the audio recordings to form cohesive narratives. For example, the entire trip "felt cold" because they forgot to bring proper clothes on the boat, but Janet and Scott couldn't wait to go back to a warm hotel room by the end of the trip, which was how the memory of their boat trip concluded.

Sonic Narration: Janet and Scott's sonic memento begins with the sounds of gulls and the motor of a boat as it pulls away from a dock. Janet's narration starts shortly after as she describes where they are and why they are taking a boat tour, then shifts to describing the scene, including the weather. Scott's voice joins the narration, providing a bit of humour to the description that they hope to see Puffins and Gulls. As the audio continues and their narration ends, we hear once again the sound of the motor, metal chains and water splashing against the hull of a boat, all of which were not present in the original audio recordings. As these sounds fade out from the foreground, we hear Scott describe the shape of the rocky outcrops they are passing, his voice buffeted against the wind and the faint sound of music from a radio can be heard in the background. Janet's narration picks up again as she describes her reaction to what Scott is telling her and her inner monologue at the time. As the trip nears its end, Janet and Scott's narration shifts to how they were feeling at the end of the boat tour: freezing cold and ready to be back on dry land but happy that it was something they got to share together. The sound of the motor and of gulls is used to mark the end of both the audio and the memory itself.

5.3 Re-imagination and Re-creation- Hana & Walter's Baby Bell

Hana and Walter brought a bell wrapped in cloth. Asking, *"Why is this bell so important to you?"* triggered a long trail of memories of their firstborn son, Chris. Because both Hana and Walter are blind, when Chris was born, they made a small baby bell wrapped and stitched in a soft cloth and attached it to Chris. Whenever Chris moved, the bell made its unique sound so Hana and Walter could locate him easily. They also attached similar bells to important objects like keys, but Chris's bell had a distinct sound they could recognize immediately. Even when he was sleeping, subtle tossing and turning would tell them where the baby was sleeping. As Chris grew older, he noticed his classmates did not have a bell attached to their clothes. Sometimes, he would stay quiet not to be spotted by his parents—mostly for fun, seldom being grumpy.

Taking the bell as a starting point, Hana and Walter recounted more dinnertime stories, including tales of how Chris ransacked the refrigerator for snacks, his favourite children's cartoons, and the songs he liked. Retelling these stories, they said it was unfortunate not to have any recordings of baby Chris crying or laughing. When

Figure 9: Hana & Walter's sonically significant object was a bell wrapped in cloth for their son, Chris.

prompted, *"How should we put these memories of baby Chris together?"*, the stories and narrations began to blur as they attempted to pinpoint a *specific* memory. Instead, Hana and Walter decided to create a brief sonic summary of an ordinary day with baby Chris. They imagined beginning with the sound they had heard in the morning, slowly moving on to the daytime sound, and later ending with the bathtime song. Building on their emotional impression of the bell sound, they slowly added more details to this memory.

Hana and Walter lived in a lively area near the train station. In the early morning around the summertime, Walter remembered the trains warming up their engines, getting ready to operate their first trip of the day. Hana recalled many birds chirping in the morning. As baby Chris woke up and started to move around the house, they would hear the bell. During the day, Chris enjoyed watching children's animations, such as the Baby Einstein series or the Magic School Bus, on a rocking chair with his *"weird"* but friendly laugh. Hana played lots of children's songs on CD. Chris had a big smile for a particular song that Hana would dance and sing along to beside his cradle. As the song finished, baby Chris went *"Weeeh,"* asking for an encore. Hana and Walter then recalled a long-forgotten children's song that used to be Chris's bathtime song. Every evening during Chris's bath time, his parents would sing the song together. The song always ended with a countdown followed by *"the splash"* as baby Chris was dipped into the bathtub. Hana and Walter were genuinely surprised as lyrics slowly came into their mind when they tried to sing the song together.

For their sonic memento, Hana wanted to record their voices, singing the bathtime song together with Walter, which takes an essential part of their memory. Additionally, Walter wanted to record his own brief description of this sonic memento in case they would share it with others. Together, we reviewed sounds from sound databases, adjusting volumes and timing to appropriate levels, and edited and mastered a short 1-minute clip. During the process, Hana and Walter actively gave real-time feedback, engaging in choosing and modifying sounds. The final version is a retrospectively recorded memory and could not contain all the original sounds they wished to include, but for Hana and Walter, it highlighted how they would want to remember baby Chris, all triggered by a simple bell sound. Interestingly, while no remarkable event was associated with the bell sound, this cherished object and its original sound prompted a recollection of precious day-to-day memories. It helped Hana and Walter recall the overall feelings, atmosphere, and mood brought back by the bell.

Sonic Narration: Hana and Walter's sonic memento starts with the gentle jingling of the bell as it is the gateway to their cherished memories of baby Chris. With American robins chirping, a bird commonly found in that area in summer, baby Chris's favourite children's song that Hana used to dance comes in. As Walter's short narration explains that these sounds are the memories of their son, the children's song gets louder, and the lyrics are heard. A few more jingling sounds depict baby Chris's movement throughout the day, followed by a subtle 'thud' of the fridge door closing. Trains and cars fill the background, creating a relaxing start-of-the-day ambience. As the day gradually fades away, the scene transitions to Hana and Walter bathing with baby Chris, singing the bathtime song together and counting down to the splash.

6 DISCUSSIONS & IMPLICATIONS

Participants possessed personal audio recordings but refrained from actively sharing them with others. Participants expressed concern that those who were not involved in the recordings might not understand, interpret, or empathize as deeply as themselves [96]. Yet, our participants had a desire to share experiences, memories, and emotions associated with the recordings with their loved ones. As Janet stated, *"Everyone has a different way of remembering things. People do try to include people who are blind or have whatever disability and make them feel like they are part of the situation as well."* Participants and their partners at the co-design workshop aspired for new ways to facilitate shared and inclusive experiences for memories captured through sound. However, they also raised concerns about photography dominating the creation of 'shared memories' among their sighted counterparts. They questioned, *can sound be a proper alternative*?

In what follows, we detail (i) design opportunities to promote collective remembering that encompass both people with sight and blindness and (ii) design recommendations to contribute to the design space of sonic memory in terms of remembering through

sound. We acknowledge that these design opportunities and recommendations come from our participants. We reviewed multiple touchpoints during a year-long ongoing, collaborative, and engaged design process aimed at respecting the positionality of our participants.

6.1 Collective Remembering through Sound

Sound memories have distinct attributes compared to visual memories. When sharing memories with photos, visual cues prompt people to look at the image, while auditory cues—separated from the visual cues—facilitate reflective conversation. In contrast, when sharing audio recordings, auditory cues must be primarily used for listening to the audio rather than engaging in reflective conversation. It is challenging to verbally describe the experience when the audio is played as the mental focus for listening and reflection may be easily disrupted. However, sound can be a powerful medium for evoking desired moods and conveying the emotions felt by participants when the audio was recorded. We found that fostering mutual understanding is critical when revisiting sonic memories together. Reflecting on our collaborative design process with the participants, we outline four key attributes of sound that are valuable in bringing people together to collectively remember memorable moments.

6.1.1 Emotional Layers in Sound. Participants kept certain recordings (e.g., soundscapes, weddings, family reunions, trips and vacations) for many years, undergoing deep grief when losing them. What makes these audio recordings special is that they hold more than sounds—they carry strong feelings and emotions that go beyond what can be heard. As Ray put it, *"It's really important for other people to understand how someone who is blind can remember things that have happened that are special to us, maybe a little bit differently".* Throughout the co-design process, we learned various sound elements can be placed in the **foreground**, **middle ground** and **background** to offer a rich, reflective sonic experience. This form of classification, used by Schafer, assigns terms such as foreground and background to organize and describe sonic experience [79], extending concepts of figure and ground from visual analysis. Moreover, we observed sounds can move between layers, drawing attention to specific aspects of the environment to invite the listener through guided moments of reflection.

Foreground sounds draw attention to audible cues, such as powerful shouts in *Ray & Michael's Sparring Highlight*, strong gusts on the ocean in *Janet & Scott's Boat Trip*, or the children's song in *Hana & Walter's Baby Bell*. Foreground sounds extend our previous finding on *Focused sound* in audio recordings [96]. While focused sounds "commemorate close social relationships", foreground sounds offer a sonic cue to a unique spatial and temporal relationship. They exist as signals—or *sound marks* [78]—to translate a sonic message that requires an individual to listen. Beyond social relationships, foreground sounds leave strong impressions on the listeners, often becoming the starting point of the conversation that touches memories in the recordings. While most of the 'highlights' in audio recordings that participants remember and cherish come from the foreground sounds, foreground sounds are not easily reconstructable.

Background sounds provide depth and create an overall tone, forming the mood of a recording while also providing context to the location. Background sounds can be white noise from a certain place or a soundscape of the surroundings. This also develops our understanding in line with earlier findings on *ambient sound*, which is used for people with blindness to "capture emotional feelings and atmospheric timbre" [96] by providing spatial and temporal qualities in a recording. Having these qualities in sound provides reflective and relational experiences, such as the distance between the time of recording and the time of listening (temporal), navigating beyond and outside of the sounding space and time as viewing sound as a *performer* with a location (spatial) rather than simply an aspect of an environment [52]. As we have found in listening practices, these qualities helped us to carefully position ambient sounds in the background, which could reconstruct the atmosphere [17] that resonated with the background sound in participants' memories. For instance, we added the sound of birds in Hana & Walter's Baby Bell. Knowing the exact location of their house and season narrowed our search for commonly spotted birds in their area in Summer, leading us to the North American Robin. This level of specificity helped create a distinct atmosphere back in the time that was perceived as emotionally and sonically strong and meaningful.

Lastly, ***middle-ground sounds*** fill the space between foreground and background, providing additional information about the scene to contribute to the overall composition of sound and acting as a transitional space for movement between layers. As our participants reflected and described, sound elements in their recordings constantly changed and shifted. Sounds in the foreground can fade into the middle ground while still contributing to the sonic space but with less attention. For example, in Janet & Scott's Boat Trip at 5:05, a tour guide plays an important role in the foreground but suddenly fades out when Janet & Scott's narration comes in. However, the tour guide keeps having a presence to support the tone and contribute to the overall atmosphere of the recording.

The interplay of sound layers creates a rich, intermixed, and dynamic auditory landscape that takes participants back to when the memory was made. Upon sharing the final versions of the sonic mementos, our participants appreciated the auditory landscape as it made them feel like they were right back in that moment, reliving it with a heightened sense of being there. As **Alan** noted, *"If there is no sound, I cannot recreate the scene."*

6.1.2 Framing the Context in Audio. Framing, where memories start and end in a sonic memento, becomes essential in memory-making through sound. Participants reported that they often find themselves caught up in the memory from the first hint of a sound. Even everyday sounds that may seem unrelated to the main memory somehow fit into the bigger picture, like a puzzle where these pieces blend seamlessly. Building a comprehensive frame for the memory, carefully shaped by sound, allows our participants to bring back memories and old feelings. Our findings clarified how memories evoked by the initial sound in a recording shape the memory trace elicited by the recording. This can happen slowly with a single sound, such as how Hana & Walter's Baby Bell begins with a quiet bell sound, or more immediately with strong energy, like Ray & Michael's Sparring Highlight.

Our participants paid attention to how their memory should close at the end of the recording. Ray wished to conclude their highlight by transitioning to a relatively calming atmosphere of catching their breath and exchanging encouraging words with each other. Hana & Walter asked to close their recording with the splash sound, as taking a bath had always been the last routine for a typical day with baby Chris. Janet & Scott carefully scripted their last lines with a quick recap of their trip, appreciating the time they enjoyed together. Framing memories in sound involves deciding and integrating particular contextual qualities. Putting contextual qualities in an audio recording can determine whether a recording is for personal reflection or social sharing. If it is only for participants themselves, the audio can have less context and be more personal, something they want to return to. On the other hand, participants wanted more context for sharing with others, like how Walter wanted to add a short description at the beginning of the Baby Bell. Narrations are needed to provide the context and tell a hint of backstory on what to expect, similar to how visual cues in photography provide where the photo is taken at a glance.

6.1.3 Pace and Length for Reflective Absorption. The pace at which participants accept and digest sound elements in audio recordings influenced the collaborative listening experience. While participants tend to *"crank up the speed"* when listening to be more efficient for practical uses (e.g., receiving notifications, reading emails, browsing websites, etc.), they also see the value in slow listening. Similar to the artifacts (e.g., [62, 65, 73, 85]) designed with Slow Technology [38] for fostering a deeper understanding of self and social relationships, at a slower pace, participants were soaked in each layer of sound, catching key emotive nuances in voices and setting boundaries on what memories they are diving into. This eventually led participants to enjoy audio at normal speed, which sighted people are accustomed to. We observed that slowness in sound is related to the ***arrangement of the sonic elements in sound layers***. For Janet & Scott's Boat Trip and Hana & Walter's Baby Bell, participants wanted to space out the sound elements with mellow overlapping sounds to transition to the next scene. Placing sounds at a gentler pace helped them dive deeper into the sound, allowing mental space to let emotions flow and connect to the moments they have saved. For instance, Janet & Scott's Boat Trip was expanded from a 2-minute audio recording to a 7-minute skit, but regardless of the length, Janet engaged in a highly focused and absorbed listening experience with Scott, listening to the final version without speeding up. The ***length of audio recordings*** also contributed to the slow pacing on top of spacing the sound elements. While Ray liked a 1-minute Sparring Highlight, he also desired to create a longer version for his own personal use to consider and enjoy. For the 1-minute highlight, Ray felt rushed because he was *"constantly forced [his] brain to shift through the scenes."* He wanted to find a way to slow it down for the purpose of reflection. Often, our participants created extended audio recordings as they usually let the recorder run in the background, often ending up with multi-hour recordings. However, as participants pointed out, they do not listen to the whole thing, both for themselves and with sighted others, because they do not have time for it and easily lose interest. In this sense, participants enjoyed the extracted highlights from the participatory field activities. However, as Ray and Alan criticized, editing sound independently requires time and effort, marking real practical difficulties that could emerge.

6.2 Recommendations and Considerations for Remembering through Sound

From our collaborative experience, creating sonic memories together felt like a reflective ritual. We sat down and dug into the memories, remembering things they had forgotten (e.g., bathtime song in Hana & Walter's Baby Bell). As a result, sonic mementos act as an entry point to a meaningful reminiscence experience for our participants and their important others who wish to remember things together through a mix of sounds, feelings, and stories. Next, we further interpret findings to detail opportunities for future HCI research and practice aimed at mobilizing sound for remembering.

6.2.1 Voice as a Resource for Temporal Reflection. In our design journey, our participants repeatedly appreciated the significance of voices. While voices carry intricate nuances and expressions for evoking memories and emotions, such as pitch, tone, and prosody, we further observed that voices can add a temporal dimension to sonic memory. When Janet played her audio recording of the boat trip during the co-listening session, Hana and Janet immediately noticed her voice was *"young"*. Similar to how individuals with sight reflect upon the passage of time while looking at photographs of themselves, our participants also experience the ***flow of time*** by listening to their own voices in the past. As Ray described it as a *"time-loop experience"*, a complex set of memories in the recorded voices resonates deeply, creating a strong sense of connection with the past and the people who were part of those moments. In this vein, voice can offer a new perspective in exploring time. As discussed in 5.2.1, our participants feel the flow of time when listening to their voices in old audio recordings. In these recordings, their own or important other's voices were captured at a time from the past, rekindling nostalgic feelings and allowing them to reminisce.

In the HCI and design community, there is a body of research on incorporating temporality into designing with personal data to foster a more holistic, meaningful and reflective experience (e.g., [19, 51, 63]). Yet, temporal qualities in voices have not been actively explored in the HCI and design communities. Our observations suggest voice has the capacity to produce creative temporal patterns to be applied to interactive systems in personal, social and cultural contexts. However, we learned from our participants that voice recordings are relatively more abundant than other collections, such as music and photography. One approach to negotiate with this limitation is to design for longer-term engagement—interactions that last long, such as dialogues with significant others or family members [41]. For example, one design opportunity could be creating a voice archive for people with blindness to collect treasured descriptions gifted by sighted people around them. As outlined in our earlier publication, people with blindness treasured descriptions of visual concepts (e.g., colours) or natural phenomena (e.g., sunsets, stars in the sky) provided by sighted others as they "look through someone else's eyes" [96]. Giving a physical or digital form for cherished descriptions in their own or loved ones' voices with temporal metadata (e.g., timestamps) can be a meaningful personal collection for people with blindness.

6.2.2 Navigating and Condensing Extended Audio Recordings. Our research revealed two primary limitations that emerged when our participants were required to handle lengthy audio recordings that held cherished memories. Participants struggled to (i) efficiently navigate through long recordings to find specific points of interest within the recording and (ii) translate the recording into a condensed version. Several design strategies could be mobilized to tackle these limitations. First, integrating markers that can be jumped to saved timestamps in the recording can improve navigation. These markers could serve as guideposts, allowing people with blindness to jump to the key moments within the recording swiftly. Then, condensing a lengthy recording can involve pinpointing its highlights. This process requires identifying the most meaningful segments that encapsulate the essence of the memory in the recording. From the participatory field activities, our research team was able to cherry-pick the highlighted moments on their behalf because some participants forgot to give a cue as they were too absorbed in the moments. Yet, making a 'less demanding interaction' to mark the highlight without disrupting the focused listening experience could be a design challenge. To avoid interrupting in situ moments of experience, recordings can be reviewed later to add the markers manually, or they could be added in an automated approach through designing a machine learning algorithm to review recently or frequently accessed timestamps to mark possible points of interest as highlights. Once these markers are created, AI-assisted algorithms could be leveraged to progressively identify and generate highlights around the marked timestamps automatically. This could not only save time but also offer people with blindness an alternative perspective on their memories, potentially unveiling serendipitous moments. Reflecting on section 5.2.3, this AI-assisted algorithm approach could also consider the length of a condensed recording, providing more control over the length of the sonic highlights to cater to varying levels of sharing needs. Some memories might be suitable for longer excerpts for detailed storytelling (e.g., Janet & Scott's Boat Trip), while succinct snippets for quick recollection might be sufficient (e.g., Ray & Michael's Sparring Highlight). These design suggestions to navigate and condense extended audio memories require a careful balance between technological assistance and user agency. By incorporating markers, highlights and the AI's capabilities, this approach may allow much leeway for people with blindness to tailor their extended audio recordings while respecting individual preferences on their cherished memories.

6.2.3 Designing for Few. Across our 12-month design journey with participants, we found that although they collectively viewed sound as an essential and primary medium to capture key life experiences, they also did not own large collections of audio memories. While some participants frequently make audio recordings, most are for practical purposes, and only a small fraction of the recordings created on special occasions truly take part as cherished audio possessions for revisitation. This signifies that making audio recordings for memories is not a daily routine for many participants. This seems to be partially because they *"got out of the habit."* Despite having easier access to make audio recordings (e.g., digital recorders and smartphones), maintaining a large, rich audio collection nonetheless required too much time and effort. These findings show there may be value in recognizing quality over quantity and underscoring the depth of meaning that a small number of selected audio possessions hold. This perspective runs counter to the trend in the HCI and design community of designing with abundant personal data for deeper reflection (e.g., vast photo archives). *Designing for few* could offer an alternative approach to engage the effects of information overload [47]. Indeed, some participants commented on how having an excessive number of cherished audio mementos could potentially *"dilute"* their significance. They were resistant to having an overabundance of audio recordings that may lessen the emotional impact of each individual memory.

Designing for few can build on and extend the HCI and design community's trajectory of values-oriented research aimed at creating interfaces that enhance self-reflection, inner growth, mindfulness and fostering social relationships by celebrating the significance of a carefully curated set of memories [38, 80]. Reflecting on the co-design workshop on sound-based reminiscence revealed that memories are not static entities but are continually reconstructed every time they are evoked, constantly influenced by the atmosphere, mood, emotion, people and other surrounding environments. This suggests that future design initiatives aimed at capturing, augmenting, and re-experiencing a smaller set of sound-based mementos do not necessarily result in people embracing few memories; rather, they emphasize the richness of each personal and social experience elicited.

7 LIMITATIONS AND FUTURE WORK

In this paper, we have described our 12-month co-creative design journey that arrived at the final co-design workshop with 7 participants. We have critically reflected on three sonic mementos from the workshop and the insights we encountered in our collaborative design process with participants. We aim to better understand how people with blindness use their personal audio recordings to look back on their past life experiences. Through a nuanced, carefully carried-out exploration, our research marks the importance of a prolonged, iterative design process that is interwoven with multiple touchpoints. We humbly recognize our decision-making process was imbued with a remarkable level of engagement, enthusiasm and dialogue. Participants, their loved ones, and researchers collectively contributed a steady stream of descriptive narratives and impressions. The significance of participants' voices, stories and emotions within their treasured audio recordings played a pivotal role in this design process. We interpreted these accounts to propose design recommendations and considerations to support future HCI research and practice investigating remembering through sound.

However, we acknowledge that there are limitations in this research. First, our design recommendations stem from the situated and nuanced experiences of a small group of participants. While these insights may serve as inspiration for researchers and practitioners working on related topics—the primary reason why we aimed to detail our design journey—these recommendations may not be easily scalable to undertaking a similar design process in a different context, especially when working with people with different social, cultural or geological background. Second, during the brainstorming of participatory activities, our research team focused on participants' words during the interview as a reflection point

to facilitate discussion and ideation on activities participants could choose. An alternative approach could have involved a separate gathering or discussion dedicated to designing the activity. For instance, engaging in a collective discussion conducted with various design activities (e.g., role-playing, body storming, arts & crafts, etc.) or with design toolkits might have yielded different activity ideas. Third, the cross-checking of data with the participants could have been executed differently. Despite allocating dedicated times, either at the beginning or end of each session, to share our analysis and elicit continuous feedback, there is room for improvement in implementing opportunities for feedback exchange. For instance, hosting more frequent get-togethers throughout the design process may have been beneficial. In hindsight, when meeting in person is challenging due to long travel distances, scheduling constraints, or pandemic situations, we could have explored other forms of communication channels, such as online Zoom meetings or group calls. Clearly, there are opportunities for working with blind participants beyond physical settings.

Throughout the research process, we have grappled with a fundamental question in co-design: Who takes the lead in the design process? In our next steps, we remain committed to a long-term collaborative approach to shaping meaningful sonic memories that resonate with people with blindness, reflecting their own unique perspectives, values, desires, and aspirations. In our future work, building on the three design opportunities suggested in this paper, we will continue engaging in a co-design process to collaboratively explore possible creative forms, materials and interactions with participants. This step will inform the design, making, and implementation of participants' sound-based mementos by creating a small set of uniquely designed research artifacts that can be lived with the participants in their homes.

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