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Designing with Senses:
Creating Interactive Multisensory Experiences in Public Space

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Designing with Senses: Creating Interactive Multisensory Experiences in Public Space

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Abstract

Public spaces are made to be shared and accessible to the general public. As spaces for social lives and activities, public spaces act as the platform for spontaneous events to temporarily connect people. They are engaged with almost all human senses, including the five basic senses – sight, sound, smell, taste, and touch – and along with the bodily senses of proprioception and kinaesthesia. This thesis proposes the inquiry of how to prompt new ways of social interaction in public space through multisensory digital experiences. Through establishing contextual information on public space, sensory and multisensory perception and studying research and design precedents that follow sensory design. This thesis then identifies potential design opportunities and begins with on site observation and pilot prototypes to experiment with modes of interaction and participation. After reflecting on the initial explorations, I produced two redesigned prototypes — an interactive sound-material interface that uses artificial grass to defamiliarize natural materials, and a computer-vision enabled sand table interface for sound composition.

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1. Introduction

*“Spaces, places, and buildings are unquestionably encountered as multisensory lived experiences. Instead of registering architecture merely as visual images, we scan our settings by the ears, skin, nose, and tongue.”¹ - Juhani Pallasmaa, *The eye of the Skin**

In the book *The Eyes of the Skin*, architect Juhani Pallasmaa argues about how the modern built environment has become a place that is heavily biased towards vision, resulting in designs that suppress other senses and flattening our perceptual presence.² Pallasmaa explains that besides the imagery, the built environment is essentially embodied, physical, and embedded with sensory experiences.³ The act of questioning the over-emphasis on sight has raised increasing awareness from other architects, urban designers and scholars to reflect on the design of built environment and living spaces.

The focus of this thesis is how to prompt new ways of social interaction in public space through multisensory digital experiences. Specifically, it poses questions two main questions:

What is the relationship between sensory and multisensory experiences and public spaces?

What are the design considerations of building interactive digital experience in public space?

This research is centered on a specific type of space – public space. In the following chapters, I start with the review of related literature and studies on defining and understanding public space and its characteristics. I consult two fields of research — cognitive science and design studies — for background and theory on sensory and multisensory perception and on the practices of sensory design. By going through a selection of related practices, I center on materiality and interaction, experience and social interaction as the key aspects of this research. Following the background and design principles, this thesis explores its line of inquiry through pilot

¹ J. Pallasmaa, “Architecture and the existential sense: Space, body, and the senses”, in *Art and the senses* (2011): pp. 579–598.

² J. Pallasmaa, *The Eyes of the Skin: Architecture and the Senses* (2013)

³ Ibid.

experiments, and later the development of redesigned prototypes. Three prototypes are prepared: *Grass Pad*, an interactive sound-material interface that uses artificial grass to defamiliarize natural materials; and *Sand Table*, a computer-vision enabled sand table interface for sound composition. Finally I conduct an evaluation of these interfaces to examine the multisensory experiences. The evaluation compares indoor (private space) and outdoor (public space) experiences with these interfaces to see how people's senses are engaged in and relate to their surrounding environment.

The main contributions of this work are:

1. Creating a list of design considerations based on three key aspects: materiality, sensory and multisensory experiences, and social interactions.
2. Providing a workflow of design process and two proof-of-concept prototypes, *Grass Pad* and *Sand Table*.
3. Proposing methods of evaluating the design prototypes.

2. Background

In this chapter, I introduce the related context and theory that this thesis lies within, and the existing projects and research I refer to as precedents. The section is organized into three categories: *public space*; *senses and multisensory experiences*; and *sensory objects and installations*.

2.1 Public Space

2.1.1 Definition of Public Space

Public spaces are properties that are open and accessible for public usage. They act as the centers of social life in cities, contributing to the well-being of communities and residents.⁴ People can gather and interact with each other without being bound by private relationships.⁵ To describe the social quality of spaces, philosopher and sociologist Henri Lefebvre defined a spatial triad for breaking down the components of spaces into three elements: the perceived (physical and material space), conceived (idea and representation space) and lived (living and experience space) space.⁶ The social aspects come from the built relationship of how people understand, interact, and experience not only the physical spaces, but also the endowed meaning and events that happened in the space. For public spaces, the activities consist of both personal and collective experiences. Geographer Yi-Fu Tuan holds a similar point of view on unpacking how people “experience” in book *Space and Place: The Perspective of Experience*, a seminal piece of literature on the study of human geography. According to Tuan, “space” can be described as a physical environment and location, and can turn into “place” under the influence of human experiences. Tuan sees “experience” as the overall term that explains how people learn and construct reality.⁷ The process of experience involves sensation, perception and conception, connecting to the five senses (physical) and the indirect mode of symbolization (conceptual).⁸ Based on this definition, placemaking in public spaces can be seen as building meaning and experience connected to the spaces.

⁴ Damian Collins, Sophie L. Stadler, in *International Encyclopedia of Human Geography (Second Edition)* (2020)

⁵ “Inclusion Through Access to Public Space | United Nations Educational, Scientific and Cultural Organization,” <http://www.unesco.org/new/en/social-and-human-sciences/themes/urban-development/migrants-inclusion-in-cities/good-practice/s/inclusion-through-access-to-public-space/>

⁶ Henri Lefebvre, *The Production of Space* (1974).

⁷ Yi-Fu Tuan, *Space and Place: The Perspective of Experience* (1979).

⁸ Ibid.

2.1.2 Understanding Public Space

Besides theoretical definitions, researchers conducted studies to inquire into public space experiences with actual sites. Urbanist William H. Whyte conducted the *Street Life Project* (see Fig. 1) with small urban spaces in New York City in the 1970s. This work used onsite observation and analysis as a method to search for the critical aspects that make public spaces vibrant.



Fig. 1: Video camera setup for documentation from *the Street Life Project*.⁹

Among all the findings and essential elements that contribute to a successful public space, “triangulation” is used as a term to describe the process of some external stimulus that creates a linkage to prompt people to interact with each other.¹⁰ This stimulus can be anything from public sculptures to street performers, as long as their presence evokes social effects of creating connections or bringing positive impressions to the space. Sensory experience is also seen as a characteristic that triangulations lead to. Using public sculptures as an example, Whyte highlighted the multi-usage of how people interact with sculptures through different senses

⁹ “Classic Documentary on Public Space Now Available Online.”

<https://www.bloomberg.com/news/articles/2011-10-03/classic-documentary-on-public-space-now-available-online>

¹⁰ William H. Whyte, *The Social Life of Small Urban Spaces* (1980).

besides vision. As Whyte described, people would interact through touching, using it as a seating area, or using sculptures as conversation starters with others. Similarly, urban researchers at Gehl studied how people create public life and connect to public spaces to come up with design principles and guidelines. To evaluate the quality of the built environment, Gehl proposed the Twelve Quality Criteria, and “protection against unpleasant sensory experience” along with “experience of aesthetic qualities and positive sensory experiences” are listed as two of the main factors that can determine the status of a public space.¹¹

Apart from sensory experiences, the findings from both the *Street Life Project* and Gehl researchers also suggest that public spaces evolve based on how people determine their usages. This echoes what researcher Quentin Stevens wrote in *The Ludic City: Exploring the Potential of Public Spaces*, where Stevens advocates an informal, playful way of engaging with public spaces. Stevens points out that public spaces serve more than their predetermined purposes, and that the spatial characteristics can affect people’s experiences and behaviors within certain spaces.¹²

Through a socio-technical design perspective, researchers from the HCI community have utilized sensing technology to study public space. In the project *Urban Probes: Encountering Our Emerging Urban Atmospheres*, to explore how digital technologies can reinterpret and expose the pattern of urban life, Paulos and Jenkins from Intel Research used rapid prototypes of interactive devices as a fail-fast and provocative approach.¹³ Starting by recording video footage of passerby interacting with trash cans and nearby spaces, the researchers framed an urban computing question to explore how urban waste can tell the story of presence and traversal of people in spaces. Then through leaving RFID tagged sample “trash” in space (see Fig. 2) and observing reactions and behaviors with the objects, the researchers harvest results on how active curiosity can form potential interaction methods.

¹¹ Gehl, “Twelve Quality Criteria”. <https://gehlpeople.com/tools/twelve-quality-criteria/>.

¹² Quentin Stevens, *The Ludic City: Exploring the Potential of Public Spaces* London (2007).

¹³ E. Paulos, & Tom Jenkins, “Urban probes: encountering our emerging urban atmospheres”, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ‘05)*.

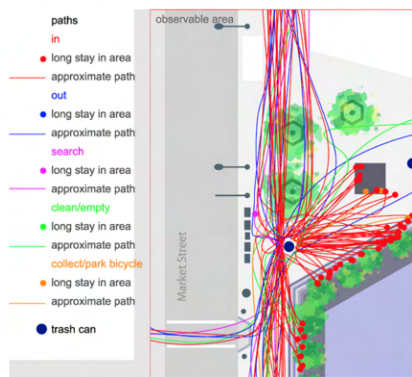


Figure 2: Diagram of the paths taken before, during and after interaction with the trashcan – Stalk 3 - 1:14pm to 2:41pm

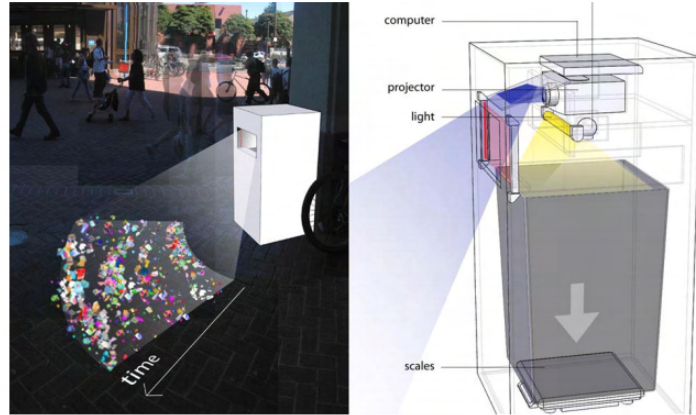


Fig. 2 (left): Diagram of traversal paths from video footage,
Fig. 3 (right): Setup and diagram of Jetsam.¹⁴

Eventually, the research product Jetsam (see Fig. 3), was built as an interactive trash can that projects its inside on nearby ground and tracks new trash over time. The projected visuals can be triggered by tossing trash into the trash can, and passersby can also observe the projected visuals changing from time to time.

This lightweight yet thorough process of identifying urban computing questions and developing rapid prototypes was continued in a subsequent research conducted by Kuznetsov and Paulos on using community participatory sensing for social engagements and public expressions.¹⁵ The researchers recruited participants with various backgrounds — from bicyclists, students, parents, and homeless people — and provided them with modular sensors that detect air quality related data (see Fig. 4).

¹⁴ Ibid.

¹⁵ S. Kuznetsov & Eric Paulos, “Participatory sensing in public spaces: activating urban surfaces with sensor probes”, in *Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10)*.



Fig. 4: Sensors placed by parents (top left, on toilet), bicyclists (top right, attached to bicycle), homeless people (bottom left, on fence) and students (bottom right, in computer lab).¹⁶

Each community ended up choosing different locations and interpreted how to make use of the sensors with different understandings, but overall the participatory experience successfully raised awareness in understanding individual and communities' relationship with public spaces. Overall, the study provided insights of possible ways to initiate community engagements with public spaces.

Through reviewing contextual background literature that helps define and build understanding of public space, this thesis identifies the research question of how to prompt new ways of social interaction in public space through multisensory digital experiences. Inspired by the *Urban Probes* research and the *Street Life Project*, I follow a similar process of first conducting on-site observation for generating design opportunities, then continuing with building and evaluating prototypes on the criticality of sensory experiences and social interactions (see discussion in Section 3.3-3.5).

¹⁶ S. Kuznetsov & Eric Paulos, "Participatory sensing in public spaces: activating urban surfaces with sensor probes", in *Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10)*.

2.2 Senses and Multisensory Experiences

To further unpack sensory experience in public space, I refer to two main categories of literature: sensory perception theories from cognitive science perspectives and design principles of sensory design that lead to applied practices.

2.2.1 Sensory and Multisensory Perception

The study of sensory perception and experience has been researched extensively in the field of cognitive science and psychology, though traditionally the senses were studied separately, and the classical theory of perception views senses as inferior to cognition.¹⁷ However, through the past decade, a growing number of discoveries have proved that even early sensory processing within a single sense is modulated by information in, and attention towards, the other senses.¹⁸ Charles Spence (Oxford Crossmodal Perception Research Group) explains in article “Senses of place: architectural design for the multisensory mind” that although humans are visually dominant creatures, what we see is often influenced by what we hear, smell, and think about the experience, and neuroscientists have discovered activities happening in multiple senses, leading to the idea of how human minds process sensory information cross senses and integrate sensory information.¹⁹ To further clarify semantics related to multisensory, Stein et al. defined a list of key terms from cognitive neuroscience studies to describe concepts relating to multisensory phenomena (See Table 1).²⁰

Term	Definition	Property the concept is attributed to
Unisensory	Any neural or behavioral process associated with a single sense	Neural or behavioral responses
Multisensory	Any neural or behavioral process associated with multiple senses	Neural or behavioral responses
Cross-modal display mode	A display with multiple display modes to channel sensory information of different origins	Display type

¹⁷ Charles Spence, “Multisensory Perception,” in *Stevens’ Handbook of Experimental Psychology and Cognitive Neuroscience* (2018), 1–56.

¹⁸ Charles Spence, “Senses of place: architectural design for the multisensory mind”, in *Cogn. Research* 5 (2020), 46.

¹⁹ Ibid.

²⁰ Barry E. Stein et al., “Semantic confusion regarding the development of multisensory integration: a practical solution” in *The European journal of neuroscience* vol. 31,10 (2010): 1713-20. doi:10.1111/j.1460-9568.2010.07206.x

Multisensory integration	A specific multisensory processing where redundant sensory information is optimally integrated to result in a multisensory response significantly different than their unisensory correspondence	Neural or behavioral response
Multisensory combination	A specific multisensory process where complementary sensory information is combined to result in a more accurate estimate of the sensory source	Neural or behavioral response
Modality-specific	The sensory information from a source that results in a unisensory response	The sensory source
Cross-modal	The sensory information from a source that results in a multisensory response	The sensory source
Spatial coincidence	The spatial overlap between two or more cross-modal stimuli of the same sensory source	The sensory source
Temporal coincidence	The temporal overlap between two or more cross-modal stimuli of the same sensory source	The sensory source
Redundancy	The reliability of spatially and temporally overlapping cross-modal stimuli of the same sensory source	The sensory source, and the neural and behavioral response
Complementary	Sensory information from the same sensory source that is not spatially or temporally overlapping	The sensory source, and the neural and behavioral response
Inverse effectiveness	The influence of reliability on cross-modal cues in multisensory processing	Neural or behavioral response
Cross-modal correspondence	Associations between different sensory forms	Neural or behavioral response

Table 1: Definitions of key terms from cognitive neuroscience studies of concepts relating to multisensory processing

This thesis focuses on activities that create multisensory combinations, and research into achieving such activities through interactive digital media. These scientific research studies and findings provide supportive theory for practice and applied fields – including art, design and architecture – to implement practices that apply sensory experience.

2.2.2 Sensory Design

In the book *Sensory Design*, Joy Monice Malnar and Frank Vodvarka consult literature and theories of perception to explore the nature of our responses to built environments. The book listed three major theories of how perception has been studied by researchers: the classic theory that views senses inferior to cognition; direct theories of stimulus-response that studied senses

individually; and Gestalt theory that regards perception as an interrelated field.²¹ The study of sensory perception can be used to explore experience within various types of spatial constructs. To develop a design typology that addresses the criticality of sensory experience, Malnar and Vodvarka argue that developing sensory awareness would provide an environment more responsive to human action and purpose.²² Curators at the Cooper Hewitt, Smithsonian Design Museum address design for all senses in the book *The Senses: Design Beyond Vision*. In the book, sensory design is defined as designs that allow people to “receive information, explore the world, and experience joy, wonder, and social connections, regardless of sensory abilities.”²³ Sensory design considers not just the shaping of objects but how objects shape us, from behaviors to emotions to experience, and sensations respond to an ever-changing environment.

Recognizing the multisensory nature of sensory perception, the prototypes produced throughout the process of this research investigates how different senses can be utilized for designing interactive experiences (see discussion in Section 3.3-3.5). For design methods, this thesis follows what *The Senses* defined as sensory design, and applies to the context of public space.²⁴

2.3 Sensory Objects and Installations

2.3.1 Materiality and Interaction

The material of interfaces has always been a crucial element in determining how our digital experiences unfold. Material properties influence how devices are embodied, how they function, and how they are experienced. Furthermore, material can influence our emotional and physical responses through interaction. Karana et al. use the term “materials experience” to describe experiences that people have through interacting with materials of a product.²⁵ In their definition, the materiality of a product is composed of four aspects: the aesthetic (sensorial) experience, the experience of meaning, the emotional experience, and the performative experience.²⁶ The researchers explored the materiality and properties of radio buttons as case studies, and tried to

²¹ Joy Monice Malnar and Frank Vodvarka, *Sensory Design* (2004).

²² Ibid.

²³ Andrea Lipps and Ellen Lupton, *The Senses: Design Beyond Vision* (2018).

²⁴ Ibid.

²⁵ Elvin Karana et al., “Material driven design (MDD): A method to design for material experiences”, in *International Journal of Design* 9, 2: 35– 54 (2015).

²⁶ Ibid.

achieve a similar tactile experience and performative quality of “tuning the radio” (See Fig. 5 and 6).

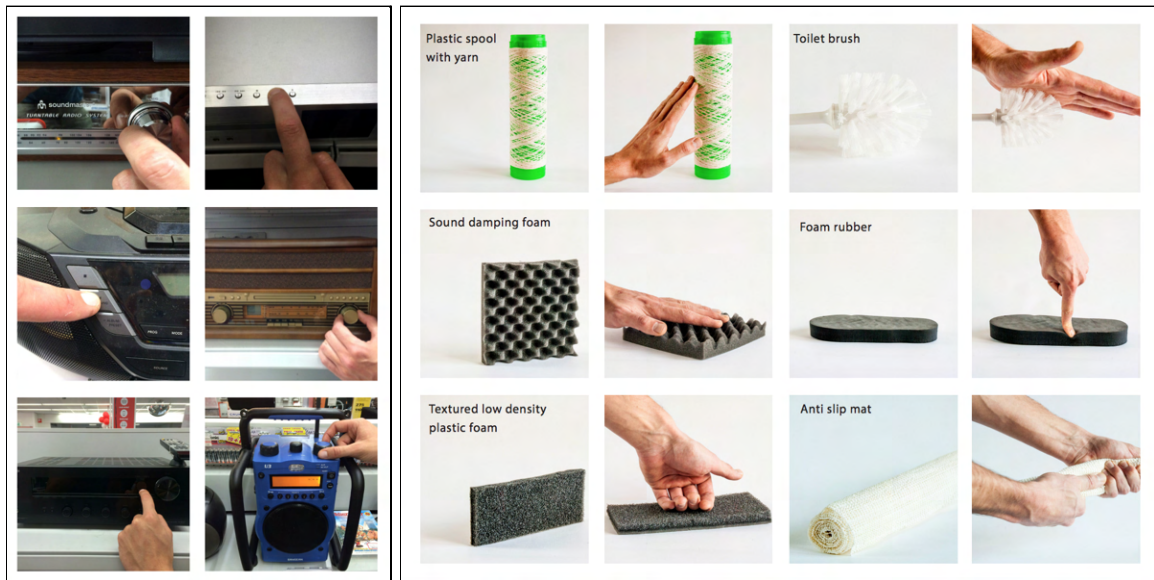


Fig. 5 (left): Studying the materiality of radio buttons,
Fig. 6 (right): Experimenting with everyday objects for material experience.²⁷

Alongside *The Senses* book, the Cooper Hewitt museum exhibited a collection of design objects that celebrate sensory inclusiveness and richness. This includes objects that are designed for spaces from domestic, to public and museum spaces.²⁸ The exhibition showcased artifacts produced by designers, researchers, and artists who experiment with the possibilities of creating sensory design objects with new materials and technologies. For instance, design studio Emerging Objects’ made custom 3D printed objects using ceramic, hemp, curry, and tea (see Fig. 7), thereby reimagining interactive experiences through novel materials.²⁹

²⁷ Elvin Karana et al., “Material driven design (MDD): A method to design for material experiences”, in *International Journal of Design* 9, 2: 35– 54 (2015).

²⁸ “The Senses: Design Beyond Vision.” <https://www.cooperhewitt.org/channel/senses/>.

²⁹ “Furry Curry Casserole Dish.” <https://collection.cooperhewitt.org/objects/1126170209/>



Fig. 7: Visitors at “The Senses” exhibition observing and interacting with Emerging Objects’ custom 3D printed objects³⁰

Yoshio Ishiguro and Ivan Poupyrev (Disney Research) also reshape listening through 3D printing techniques. They developed a system for designing and manufacturing interactive 3D printed speakers that can easily be integrated into various objects and different forms (see Fig. 8).³¹ By adapting and improving electrostatic speaker technology, the researchers were able to directly embed the sound generating electrode inside printed forms. In addition, these printed forms can also be used for further interaction opportunities such as tracking and identification using ultrasonic frequencies.³² The freedom of creating speakers in arbitrary 3D printed form expands the ways of connecting form, materiality, and interactivity.

³⁰ “The Senses—Design Beyond Vision Both a Feat and a Feast.”

<https://segd.org/senses%E2%80%94design-beyond-vision-both-feat-and-feast>

³¹ Yoshio Ishiguro and Ivan Poupyrev, “3D printed interactive speakers”, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*.

³² Ibid.



Fig. 8: A 3D printed object with speaker embedded inside³³

As people discover sensory experiences through interacting with the digital interface, the chosen material also affects how actions are shaped, thus contributing to the interactive experience and narrative. Design researcher Audrey Desjardins collaborated with technocrafter Timea Tihanyi to create a set of 3D printed porcelain cups (See Fig. 9) that embody and embed everyday ambient sounds data in their form.³⁴ Desjardins and Tihanyi produced the cups by collecting sound-level data from everyday places including Desjardins's home, a restaurant, studio spaces, and a residential street, and transforming the audio data into G-code for 3D printing. The project asks how people can make sense of their domestic data by transforming the intangible sound and noise into tactile objects, and how we might build new connections to everyday objects through a material narrative.

³³ Yoshio Ishiguro and Ivan Poupyrev, "3D printed interactive speakers", in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*.

³⁴ Audrey Desjardins and Timea Tihanyi, "ListeningCups: A Case of Data Tactility and Data Stories," in *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19)*.



Fig. 9: ListeningCups: 3D printed porcelain cups that represent data in a textural and tactile form³⁵

William Odom et al. created Olo Radio (see Fig. 10), a tangible music play-back device that arranges the user's song collection with their personal listening history to create new narratives with material explorations and listening experiences.³⁶ Olo Radio's control interface consists of three parts: a knob for sorting listening history in time related order (day, year and life), a slider for browsing through the selected time frame, and a volume knob.³⁷ The organized playlists are created through time based information. Like ListeningCups, Olo Radio tries to build novel ways of forming user's digital experiences with the materiality of the physical interface.

³⁵ Ibid.

³⁶ William Odom et al., "Exploring the Reflective Potentialities of Personal Data with Different Temporal Modalities: A Field Study of Olo Radio", in *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20)*.

³⁷ William Odom et al., "Exploring the Reflective Potentialities of Personal Data with Different Temporal Modalities: A Field Study of Olo Radio", in *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20)*.



Fig. 10: Olo Radio: music playback devices that reshapes listening history in a tangible form³⁸

Besides domestic objects, designers and researchers have also explored interactive applications in urban spaces. For example, Theodore Kofman (Cooper Union) and the project team on *Tactile City* proposed a research and design project that aims to address the challenges that visually impaired pedestrians face when navigating the city.³⁹ The prototype was a city-wide redesign of the sidewalk construction by incorporating tactile feedback and sounds as signal cues other than visual signs (see Fig. 11 and 12). Visually impaired pedestrians are guided through different textured tiles representing paths and addresses, and are informed with a combination of sound notification if they encounter construction sites or other obstacles. *Tactile City* reimagines signal cues through a different set of interactions with touch and hearing. It offers an example of how materiality and the corresponding interaction can be applied to public space in the city.

³⁸ Ibid.

³⁹ Theodore Kofman et al., “Tactile City”. <http://www.tactilecity.org/>.

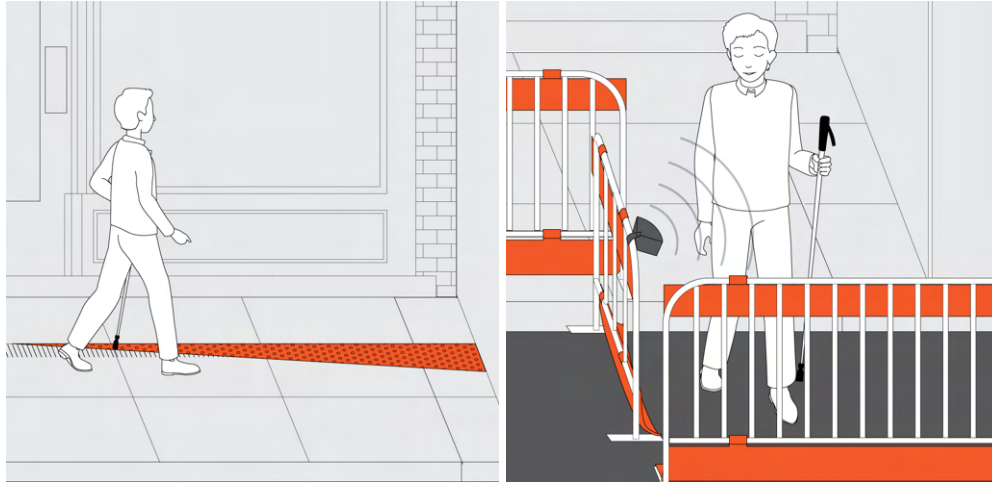


Fig. 11 (left): Tactile path with textured surface indicating construction sites,
 Fig. 12 (right): Responsive speaker guiding pedestrians to detour⁴⁰

Linda Hirsch et al. presented a materiality-based and experiential approach to urban interaction design (UIxD) in *Material Meets the City: A Materials Experience Perspective on Urban Interaction Design* by outlining and expanding on various design opportunities for urban spatial interaction involving different material experiences.⁴¹ Hirsch saw the possibilities of embedding computation into existing physical materials, challenging the existing noninteractive and inflexible traditional surfaces in urban spaces. In the section about connecting material and places with people, Hirsch proposed to design with location-based, real-time information and to increase one's awareness of the environment with material traces.⁴² Hirsch also saw the playful and social nature of urban life as the key components of UIxD, again emphasizing the importance of social interaction. echoes Quentin Stevens's advocacy for playful interaction within public spaces. This thesis also views playful and exploratory activities as potential ways of engaging people in the environment.

⁴⁰ Theodore Kofman et al., "Tactile City". <http://www.tactilecity.org/>.

⁴¹ Linda Hirsch et al., "Material Meets the City: A Materials Experience Perspective on Urban Interaction Design," in *Interactions* 29, no. 1 (January 6, 2022): 58–63, <https://doi.org/10.1145/3501358>.

⁴² Ibid.

2.3.2 Experience and Social Interaction

The book *Sensory Design* quoted humanist E. V. Walter on describing the relationship between place and experience:

*“A place is a location of experience. It evokes and organizes memories, images, feelings, sentiments, meanings, and the work of imagination. The feelings of a place are indeed the mental projections of individuals, but they come from collective experience and they do not happen anywhere else. They belong to the place.”*⁴³

In relation to William Whyte’s idea of how triangulation — building linkage with social effects — can improve the quality of a public space, designers, researchers, and artists have come up with methods for creating connections through design products and research projects.

Considering the focus of this thesis, I chose, and next present, examples that demonstrate their practices through participatory activities and/or interactive digital experience.

To investigate collective experience in public spaces, researcher Kate McLean proposed a typology of smell mapping that engages groups of participants or community members from different neighborhoods.⁴⁴ By having participants identify scents in public spaces, McLean turned the collected results into maps of collective smellscape (see Fig. 13 and 14). By encouraging people from various communities to explore and share smell information among themselves, Smellscape Mapping generates situated, embodied, and shared smell knowledge and data, thus building connections through this sensorial experience.

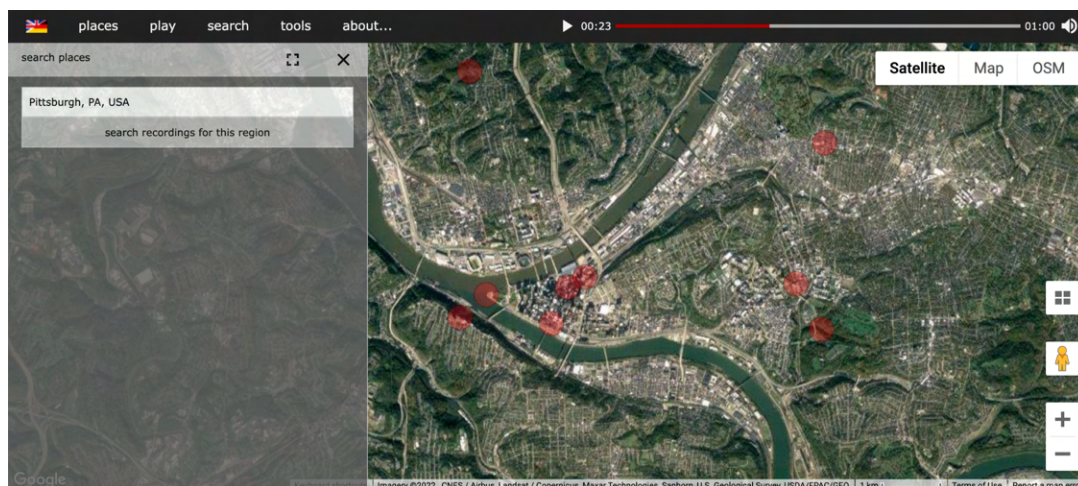
⁴³ Joy Monice Malnar and Frank Vodvarka, *Sensory Design* (2004).

⁴⁴ Katherine Jane McLean, “Nose-First: Practices of Smellwalking and Smellscape Mapping” (2019)



Fig. 13 (left): Crowdsourced Summer Streets Smellmapping Astor Place, NYC,
 Fig. 14 (right): Participants adding their findings to the map⁴⁵

A similar act of connection-building through collective participation, Radio Aporee is an interactive global soundmap dedicated to field recording, phonography, and the art of listening.⁴⁶ Users can navigate around and listen to recordings by either searching based on date and time, or on the locations of places directly. To contribute to the map, users can upload their own field recordings and make them a part of the collection. The website organizes all sound uploads by aligning them to the recording locations on the map (see Fig. 15). Although there is no direct interaction among the users prompted by the website, the sound map still holds a social aspect of participatory engagement, connecting the physical and digital spaces with people.



⁴⁵ “Summer Streets Smellmapping Astor Place, NYC.”

<https://sensorymaps.com/?projects=summer-streets-smellmapping-astor-place-nyc>

⁴⁶ “Radio Aporee :: Maps - Sounds of the World”, <https://aporee.org/maps/>.

Fig. 15: map of Pittsburgh with red dots indicating sound uploads

Designers, artists and researchers also worked with interactive digital media to form social interactions. Artist Christopher Janney has been working on the *Urban Musical Instrument* series, a collection of interactive public installations that produce sounds, since 1978.⁴⁷

Following the belief that art should be an integral part of one's everyday life, Janney experiments with various ways of building public instruments that the community can play (see Fig. 16). The sounds of *Urban Musical Instrument* installations are triggered by various interaction methods, from waving in front of light sensors, to touching or stepping onto specific locations embedded with switches. Each trigger is assigned with a specific sound, from melodic instruments (marimba, flute) to environmental sounds. Janney intends to create curious moments and a joy of discovery with passerby in public spaces, evoking a relationship between the people and their environment.



Fig. 16: People interacting with *REACH: New York* (1995) in the subway station.⁴⁸

In search of the advantages and challenges of applying new interactive technologies situated in urban space, researchers Karmen Franinovic and Yon Visell have also built a set of public sound

⁴⁷ Christopher Janney, "Urban Musical Instrument", <https://www.janneysound.com/skill/urban-musical-instruments/>

⁴⁸ Christopher Janney, "REACH: New York", <https://www.janneysound.com/project/reach-new-york/>

instruments for documenting and studying public behavior towards the installations.⁴⁹ *Recycled Soundscapes* (see Fig. 17) consists of three sculptural pieces that can record sounds from the surroundings. The recorded sounds can be played back by interacting with the interface (either through pressing a button or spinning the interface). The researchers also reflected temporality and collaboration through the design. The sound playback became richer when multiple interfaces were in use, and the duration of soundscape was responsive to the level of interaction.



Fig. 17: People interacting with *Recycled Soundscapes* (2004)⁵⁰

Another example that utilized playful and unprecedented input methods is *Acrobatic Solo for John Coltrane* created by Studio Playtronica, an interactive sound playground that celebrates the music of Jazz musician John Coltrane.⁵¹ The audience was invited to reconstruct Coltrane's classical piece not through the act of “playing” an instrument, but through interacting with a playground — jumping on the sensor-embedded floor and walking on a slackline. Audiences can play with and listen to the collaborative improvisation of the recomposition (see Fig. 18). The sounds were triggered by piezo sensors embedded in the ground to sense vibrations, and a

⁴⁹ Karmen Franinovic and Yon Visell, “Recycled soundscapes”, in *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '04)*.

⁵⁰ Karmen Franinovic and Yon Visell, “Recycled soundscapes”, in *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '04)*.

⁵¹ Studio Playtronica, “Acrobatic Solo for John Coltrane”, <https://playtronica.com/coltrane>

tension sensor thread woven into the rope to sense stretching. The studio compared jazz improvisation to walking on a rope and other playful activities, resulting in a playground that is open to all ages. The embodied and tangible quality of the installation worked as a whole, constructing an interactive multisensory experience.

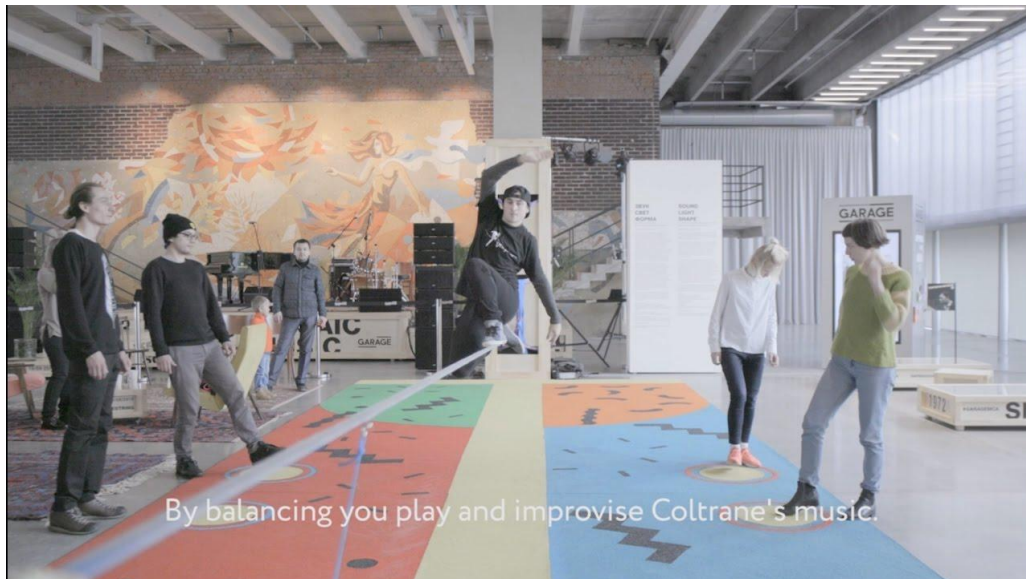


Fig. 18: People exploring *Acrobatic Solo for John Coltrane* at the Garage museum⁵²

Based on the selected precedents, this thesis centers on an approach that emphasizes materiality and material experience, as well as addressing the social aspects of active participation from users. Considering the focus of multisensory experience, I also continue on exploring how different senses can influence each other through the design products.

⁵² Studio Playtronica, "Acrobatic Solo for John Coltrane", <https://playtronica.com/coltrane>

3. Methods

Taking inspiration from existing prior practices, this thesis combines field research and rapid prototyping as first steps of pilot exploration. By reviewing the definition of public space, sensory and multisensory experiences in the Background chapter to better understand the context, I decided to follow an approach similar to the approach of *Urban Probes*. This began with on-site observations to capture people's behavior in public space and to identify potential design spaces for introducing digitally mediated sensorial experiences. The research prototypes follow the design principles of sensory design.⁵³ Considering how activities in public space are still recovering from the influence of COVID-19 and the difficulties of exploring certain senses in public settings, this research does not address or explore the sense of smell and taste.

The process of producing and refining research prototypes also fits the approach of Research through Design.⁵⁴ As I reflect based on findings from the potential design product with each iteration, I attempt to continually reshape the framing question for my research of how to utilize multisensory experience in public.

I divided the exploration into two parts: firstly initial preliminary studies and secondly improved prototypes. The preliminary studies include a series of site visits and the development of two pilot prototypes. These prototypes are based on observed behaviors for exploring materiality and interaction, as well as for building social interaction. After analyzing and reflecting on the pilot results, I next produced two redesigned prototypes that address overlooked aspects and opportunities identified.

3.2 Site Visits: Parks and Plazas in Pittsburgh

To build a better understanding of the location, I researched public spaces in Pittsburgh. Inspired by *the Street Life Project* and in hope of gathering more opportunities on forming “triangulation”, I focused on parks and plazas, and eventually picked two parks and two plazas in Downtown Pittsburgh and Oakland for conducting observation on site. I visited the sites on two

⁵³ Andrea Lipps and Ellen Lupton, *The Senses: Design Beyond Vision* (2018).

⁵⁴ John Zimmerman, Jodi Forlizzi, and Shelley Evenson, “Research through design as a method for interaction design research in HCI”, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*.

sunny weekend days in September 2021. The field visits were also preparation for selecting an ideal installation site for the design prototypes.

The list of sites include: Agnes R. Katz Plaza, Allegheny Riverfront Park, Point State Park and Schenley Plaza. I paid attention to the amount of people and activities happening in the space, including interaction with the space and interaction with others. For each site, I spent around 40 to 50 minutes and recorded documentation for reference through notes, photos, sound recordings, and videos.

3.2.1 Agnes R. Katz Plaza



Fig. 19 and 20: Agnes R. Katz Plaza (Sep 2021).

Agnes R. Katz Plaza (see Fig. 19 and 20) is an example of how an artist collaborated with landscape architect and urban designer to create a vital public space for the community. American artist and sculptor Louise Bourgeois created the public art installations. The commission includes a 25-foot bronze fountain centerpiece and three pairs of granite eyeball statues that can function as seats.⁵⁵ The artworks serve a combined purpose, presenting both the creator's artistic expression and practical usage that can be applied for urban public space.

⁵⁵ "Agnes R. Katz Plaza," https://trustarts.org/pct_home/visit/facilities/katz.

During my visit, I observed how and if people would interact with the installations, either with the fountain or using the statue seatings. Because the place is located next to a bus stop, groups of people entered and left the space. There were also ones that stayed for a long time, with most sitting in the shades, and only a few used the statue seatings, partly because the seatings were located right in the center of the plaza. There were around 5 groups of families, although not all present at the same time. Children and families with children were the ones that went close and interacted with the fountain. Children would play with the water and walk on the edge around it.

3.2.2 Allegheny Riverfront Park



Fig. 21: Allegheny Riverfront Park, under the Andy Warhol Bridge (Sep 2021).

Although more of an riverside open space than a park, Allegheny Riverfront Park (see Fig. 21) went through urban renewal and now occasionally features installations and artworks.⁵⁶ Spaces under the bridge provide potential opportunities for events and installations. Showcased at a similar environment but beneath the Veteran's Bridge, the H3O series by The Drift and the Center for Urban Intervention Research from CMU featured site-responsive video projections

⁵⁶ "Allegheny Riverfront Park", https://trustarts.org/pct_home/visual-arts/public-art/allegheny-riverfront-park.

and musical performances respond to the materiality of water and the mediated environment in a post-internet age.⁵⁷

Unlike how Agnes R. Katz Plaza features public seating, the Riverfront Park has no pre-designed seating area. There are only riverside barriers that could be used for temporary resting, but people still made good use of it. I walked along the riverside repeatedly for most of the time, and tried to compare the differences between space with and without seating and the influence on the usage of this space. Most people gathered under the bridge, either chatting among groups or doing activities like fishing. More were in motion, doing exercises like jogging, cycling or just walking. Only a few people remained for a long time in this space.

3.2.3 Point State Park



Fig. 22: Point State Park, near the fountain (Sep 2021).

The Point State Park (see Fig. 22) is also an urban renewal project that was redesigned for better usage of the public space. It is located at the confluence of the rivers, created to turn the

⁵⁷ “H3O // 003,” Center for Urban Intervention Research (2015), <https://www.cuir.studio/h3o-003/>.

downtown space into a public green space for outdoor recreational events.⁵⁸ I spent most of my time at the fountain and by the waterside - two spots that attract people the most.

As it is a larger open space compared to the two previous locations, more people used the space for exercises like skating and cycling. Still, most remained seated around the fountain or on the stairs and edges near the water. The fountain is a much larger one than the one at Agnes R. Katz Plaza, and attracted more people in different age groups to play with the water. The park also provides different kinds of public seating and people took advantage of the variety of it.

3.2.4 Schenley Plaza



Fig. 23: Schenley Plaza (Sep 2021).

Schenley plaza (see Fig. 23) acts as the grand entrance into Schenley Park.⁵⁹ Because of its location and well provided seating, the plaza attracts a lot of people to use the space for a variety of activities, either for casual gatherings or specific events in place. Besides the center lawn and gardens, it features food kiosks and a carousel. An example of public art happening at this site is

⁵⁸ “Point State Park”, <https://www.dcnr.pa.gov/StateParks/FindAPark/PointStatePark/Pages/default.aspx>.

⁵⁹ “Schenley Plaza”, <https://pittsburghparks.org/park-projects/schenley-plaza/>.

Conflict Kitchen, a participatory art piece by CMU art professors Jon Rubin and Dawn Weleski opened at the take-out kiosk next to the lawn in the plaza.⁶⁰

Among the 4 sites the Schenley Plaza was the most crowded place I visited, with about 50 people at the place. While there were also joggers and bikers in the space, since the plaza provides both seating close to the lawn and outdoor seating that can be used for restaurants, lots of people were sitting and mostly remained seated during my visit, with only some going across the lawn seldomly.

3.2.5 Findings

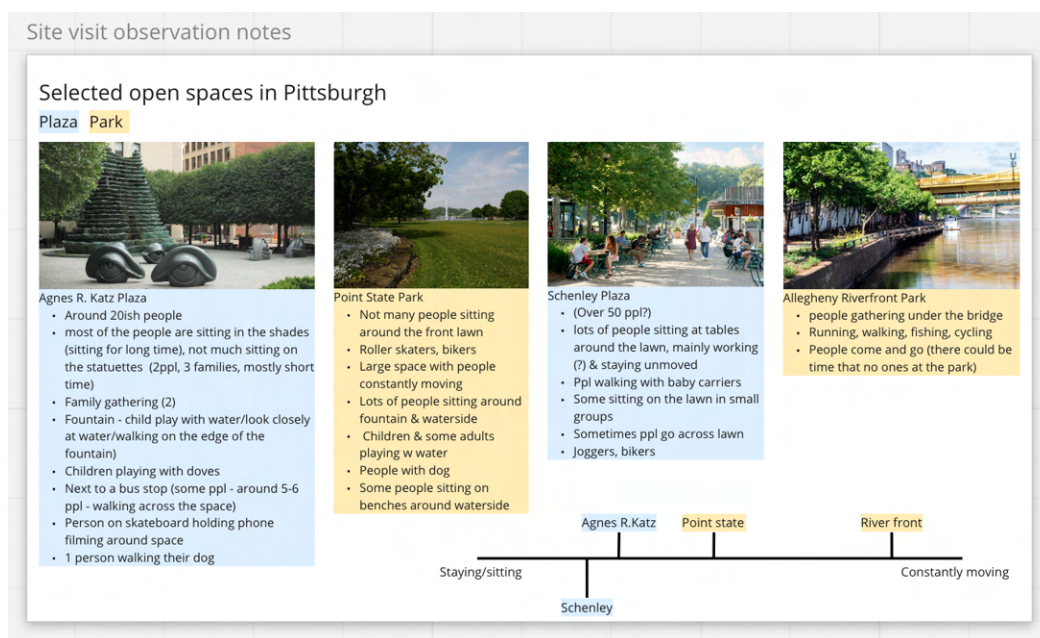


Fig. 24: Notes taken from on-site visits.

Inspired by the *Street Life Project* and by Whyte's field study, I focused on observation and documentation through different mediums.⁶¹ Whyte proposed that an effective public space would have triangulations — having external stimuli that can connect people and prompt

⁶⁰ Jon Rubin and Dawn Weleski, "Conflict Kitchen", <https://www.conflict-kitchen.org/about/>.

⁶¹ William H. Whyte, *The Social Life of Small Urban Spaces* (1980).

strangers to talk to each other spontaneously.⁶² The selected locations are all among the most popular public spaces in Pittsburgh. They also share similarities like having water fountains or being close to water, or providing a variety of seating. I compared all my visits and summarized that: seating areas are always popular, and people would use them whenever they are available. For potential interaction with triangulations in the space, families and children are the most likely groups to initiate contacts. These site visits provided an overview of the potential space for placing the design prototypes, and what types of behaviors to expect that may happen within the space.

3.3 Grass Bench: Pilot Prototype on Material and Interaction

Following the site visits and based on the observation of how people utilize public seating, I created my first small scale prototype. The prototype aims to experiment with the material characteristics and ways of interaction. As grass and plants are common elements used for designing public spaces, I explored how these natural elements, often curated as part of urban planning efforts, might affect people's sensorial experiences. I followed the idea of "defamiliarization" to reshape the experience of using public amenities to open up for critical reflection.⁶³ I chose a bench as the object to defamiliarize by turning it into an interactive device.

I augmented a bench on the CMU campus into an interactive "grass" bench (see Fig. 25) that would record the number of visitors.

⁶² Ibid.

⁶³ Genevieve Bell, Mark Blythe, and Phoebe Sengers. 2005. Making by making strange: Defamiliarization and the design of domestic technologies, in *ACM Trans. Comput.-Hum. Interact.* 12, 2 (June 2005), 149–173.

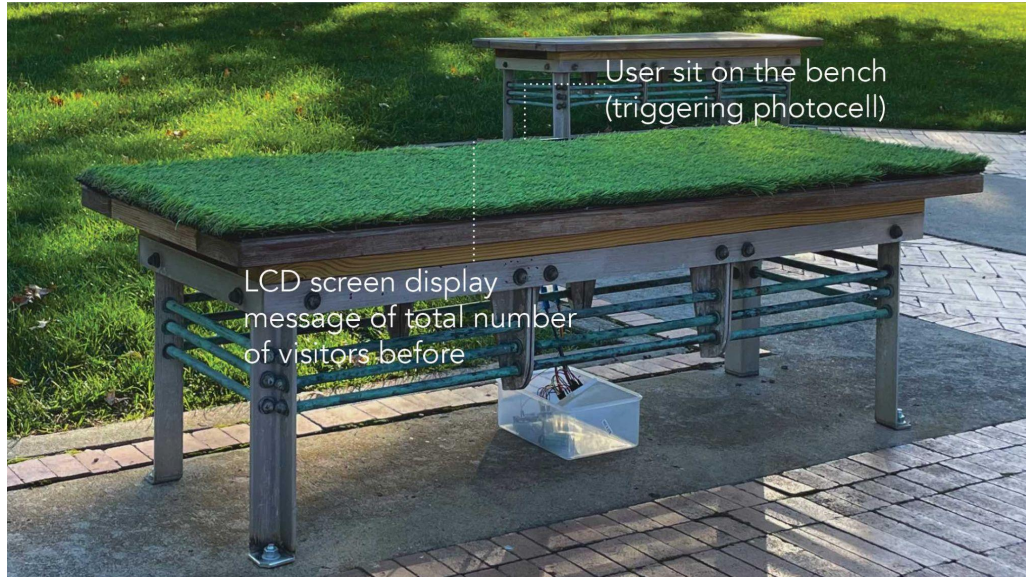


Fig. 25: Setup and interaction of *Grass Bench*.

I used a piece of artificial grass at the same size (15 inches by 25 inches) as the bench surface embedded with a photocell and a LCD screen. Once the visitor sat on the photocell, the bench would increment the count of the number of visitors and display a corresponding message on the LCD screen, greeting the visitor by notifying them how many people had sat on the bench before.

This prototype encouraged me to reflect on the connection between material characteristics and the prompted interaction. While the choice of artificial grass provided a distinct tactile feedback and seating experience, the use of a photocell limited the form of interaction, since it only recognizes presence or absence of visitors. The seating action also restricted the usage of the material, leaving minimal interaction with sensory feedback. During the development process, I was also continually comparing and reflecting on the material aspects and the underlying meaning of human-made materials versus natural materials. Thus, I decided to preserve the use of artificial grass and the contrast brought by the materiality. I also redesigned and addressed the use of haptic feedback and touch as interaction methods in the later prototypes.

3.4 Collaborative Field Sound Archive: Pilot Prototype on Participation

3.4.1 Design Process

Besides considering materiality and the sense of touch, I experimented with sound and ways of building participation through collective contribution in my second pilot prototype. I took inspiration from Radio Aporee (see section 2.3.2) and applied a lightweight process for rapid testing.⁶⁴ The goal of this prototype was to observe how individuals experience space differently through listening activities, and to experiment with a potential mode of social interaction through participatory engagement. I listed out the instructions on providing basic information on this activity and guiding questions to describe sound textures in a Google Form (see Fig. 26). Doherty Stairs at the Carnegie Mellon campus was chosen as the site for this prototype. Two mini posters with QR codes linked to the form were visibly placed at the site (see Fig. 27 and 28).

⁶⁴ “Radio Aporee ::: Maps - Sounds of the World”, <https://aporee.org/maps/>.

Section 1 of 2

Collaborative Field Sound Archive

You're invited to capture up to 30 seconds of audio using your phone at or nearby this location. You can stay in one location or feel free to walk around and explore the space. The sound could be natural and ambient, noises made by you (talking, vocalizations) or some combination of the two.

The sound you contribute will be used as part of a pilot experiment for my Master of Computational Design thesis. I am exploring how interactive installations in public spaces to create multi-sensorial experiences. The sound you contribute won't be labeled or identified as yours, neither will your email or other identifiable information be used as part of this project. Please feel free to reach out (yanwend@andrew.cmu.edu) if you have any questions. Thank you!

Please upload your recorded sound file here: *

Add file
View folder

Which option(s) fit the best for type of sound you recorded? *

☐ Ambient or environmental sound
☐ Percussive sound
☐ Sustained sound
☐ Natural sound
☐ Human made sound
☐ Other...

If you could, provide a name for the recorded sound:

Short answer text

Fig. 26: Collaborative Field Sound Archive Google Form



Fig. 27 (left): Mini posters on site,
 Fig. 28 (right): Doherty Stairs

This structure allows quick experimentation and evaluation on the mode of participation. In the Google form, participants are prompted to record a short (up to 30 seconds) sound piece at Doherty Stairs. After uploading the sound file, participants were also asked to categorize their recorded sound by choosing from a list of: ambient or environmental sound; percussive sound; sustained sound; natural sound; or human made sound.

3.4.2 Results collected from the Google Form

This experiment was completed during the campus's winter break and was still under the influence of COVID-19. The archive accepted submissions from December 2021 to the end of January 2022, and collected 13 responses in total. The results collected from the Google form are shown in the graphs and descriptions below (see Fig. 29 - 31).

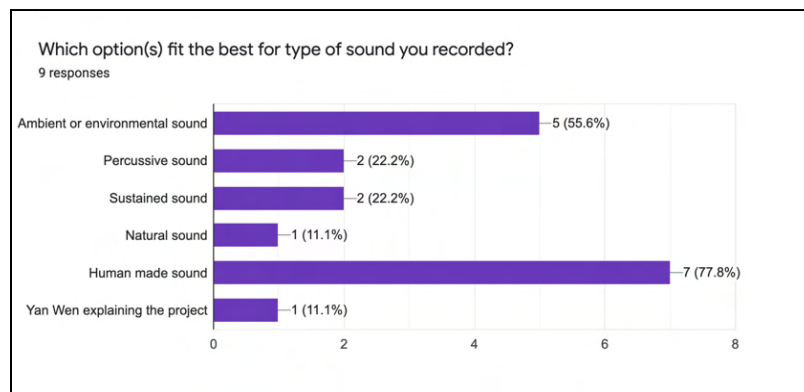
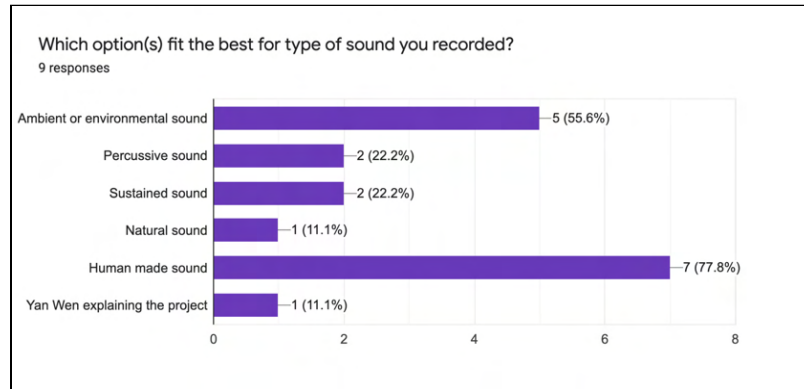


Fig. 29 (top) and 30 (bottom): Bar graph summarizing the submissions

If you could, provide a name for the recorded sound:

7 responses

- walking in snow, shitty iphone recording
- walking up a staircase at night
- footstep sound
- Walking up Some Stairs
- Building AC and talking
- Building hum, distant child, breathing
- chips

If you could, provide a name for the recorded sound:

1 response

- litany against fear

Fig. 31: Descriptions provided by participants

Three commonalities among the sound samples are: walking while recording, talking while recording, and evident weather changes. Most of the participants recorded their sounds while walking around the site, trying to record sounds from movements. Talking while recording was also common, with 4 recordings featuring human voices, with a variety of conversations, descriptive narration, and short monologue. During the timespan of the exploration, change in weather also affected the types of recordings, producing noticeable changes of sound types and texture.

3.5 Reflection on Pilot Experiments

Based on the feedback and results gathered from the experiments, I collected the following findings on the materiality and interactive experience, as well as social interaction aspects as major focuses for refinement.

3.5.1 Findings on Materiality

Learning from the site visits and the *Grass Bench* prototype, and reflecting on the background literature of applying materials experience perspective to urban interaction designs, I found the juxtaposition of human-made materials and natural surroundings to be intriguing. Since artificial grass mimics the look and feel of natural materials but provides a different tactile experience, I expanded the material choice based on such quality with some variations, and decided on using thick yarn and moss to experiment under the concept of defamiliarizing urban surfaces.

3.5.2 Findings on Interactive Experience

Through building and testing out *Grass Bench* and *Collective Sound Archive*, I gathered findings on ways of interacting and on designing instructions to prompt the experience. With *Grass Bench*, the restricted interaction (covering the photocell through the act of sitting) did not contribute much to connecting the material characteristics to the sensory experience. Thus I decided to reconsider the usage of touch and tactile feedback in interaction design and digital installations, for improving the design choices for final prototypes. Other than the basic digital inputs of button pressing, methods like capacitive touch and soft switches are more related to actions of how people would actually behave in the physical environment. Based on the pilot prototypes, I found opportunities to continue shaping tactile and listening activities, and move on to explore how sound can be used as outputs to build a multisensory narrative.

3.5.3 Findings on Social Interaction

Although the interaction of *Grass Bench* involves counting presence of previous visitors, and Sound Archive attempted collective engagements, the interactions were passive and indirect,

without building actual connections that can create triangulation in public space. Thus, for the redesigned prototypes, I switched to designing for active participation and allowing multiple users to interact at the same time.

4. Findings and Evaluation

In this section, I describe the redesigned prototypes that extend the exploration of materiality and the modes of participation. The prototypes combine tactile interaction and listening, as well as encouraging multi-user interaction. The two prototypes were developed on a small scale, serving as proof-of-concept prototypes for an intended installation in public space.

4.1 Redesigned Prototypes

4.1.1 Material Exploration with Moss and Artificial Grass

I redesigned the interaction of the *Grass Bench* considering the characteristics of alternative materials. This first resulted in a multi-touch moss pad (see Fig. 32 and 33). By stroking the surface of the moss pad, users can trigger a sine wave sound to be played. Moving around and pressing on different locations of the moss pad can adjust the frequency of the sound (see Fig. 34).

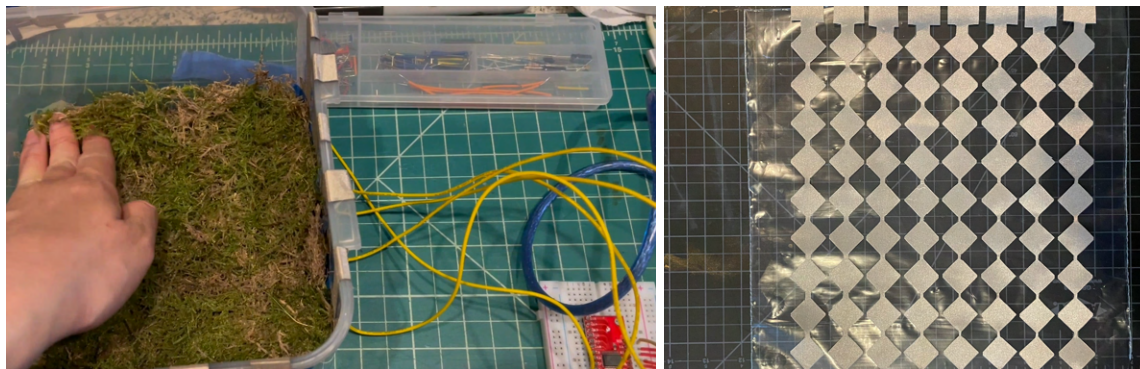


Fig. 32 (left): Multi-touch moss pad,
Fig. 33 (right): Custom built multi-touch sensor.

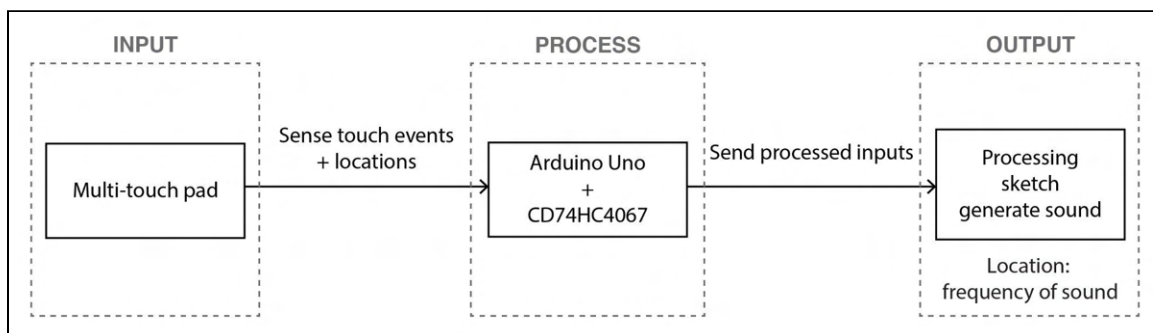


Fig. 34: Multi-touch interaction diagram.

For the technical construction, underneath the moss layer, I embedded a custom built multi-touch layer following an open-source Arduino based sensor setup.⁶⁵ The sensor was made with adhesive conductive fabric tape attaching to a thin piece of plastic sheet. The inputs from the moss pad were sensed from the capacitive grid multi-touch sensor and processed through a SparkFun CD74HC4067 Breakout module before relaying this to an Arduino Uno to trigger sound playback (see Fig. 35).

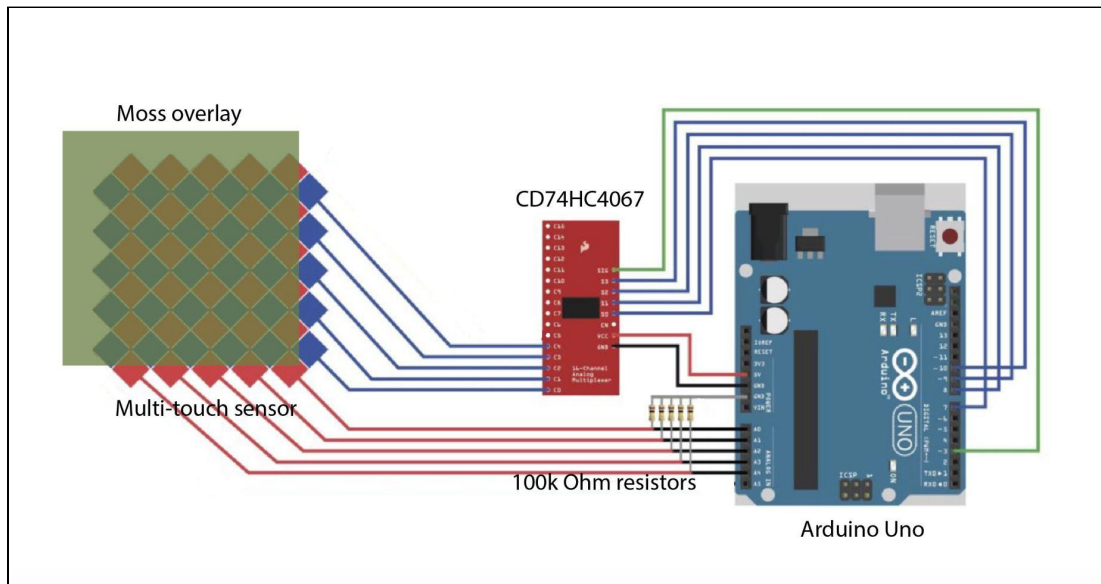


Fig. 35: Multi-touch moss pad setup modified and annotated from “Multi-Touch Kit”.⁶⁶

I also designed and built another setup with the artificial grass overlay. This setup consisted of two types of interaction: users can trigger individual sound sequences by pressing the grass pad or by holding a yarn pom-pom (see Fig. 36 and 37).

⁶⁵ Narjes Pourjafarian et al., “Multi-Touch Kit: A Do-It-Yourself Technique for Capacitive Multi-Touch Sensing Using a Commodity Microcontroller”, in *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology (UIST '19)*.

⁶⁶ Ibid.



Fig. 36: Redesigned artificial grass pad.

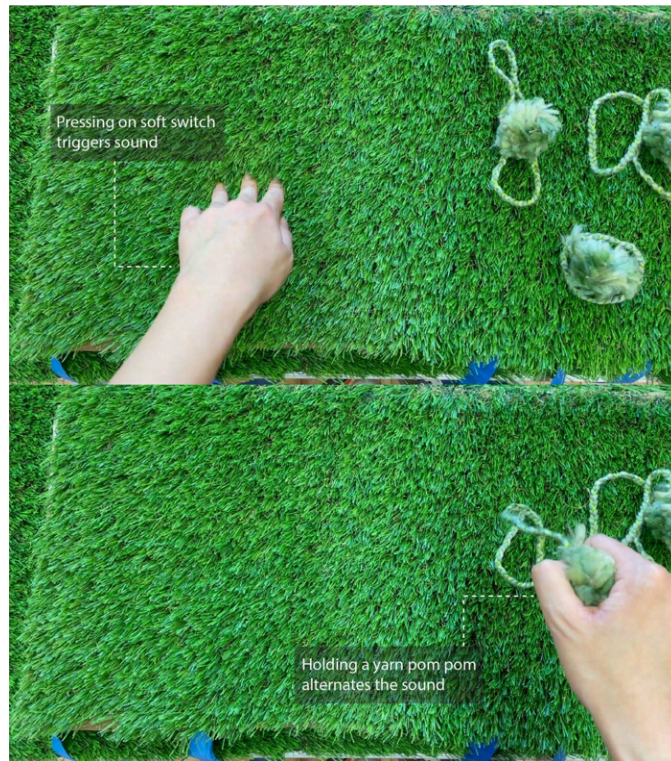


Fig. 37: Interacting with the *Grass Pad*.

I redesigned the interaction with a soft switch and capacitive touch mechanism.⁶⁷ The soft switch operates in a similar way of a tactile switch, and the pom-poms are built as custom capacitive touch sensors through interweaving conductive thread with non-conductive yarn together (see Fig. 38 and 39).



Fig. 38 (left): Backside of the *Grass Pad*,
Fig. 39 (right): Custom capacitive pom-poms.

The sensors were connected to a Makey Makey Board to process input signals. The software was built with a Python program recognizing sensor inputs as individual key inputs, and sending OSC messages to Sonic Pi, a code-based music creation and performance tool, to generate live sound sequences once triggered.⁶⁸ Each sensor was assigned with a unique sound loop in Sonic Pi to generate synth based sounds (see Fig. 40 and 41).

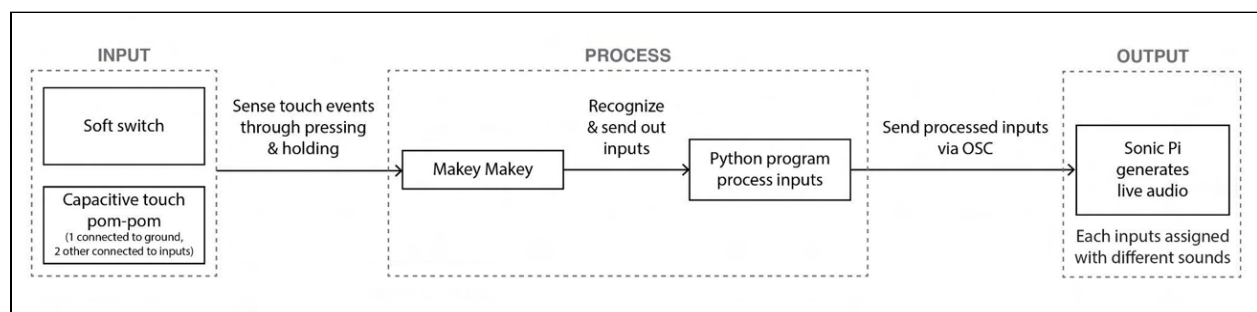


Fig. 40: *Grass Pad* interaction diagram.

⁶⁷ "HOW TO GET WHAT YOU WANT," <https://www.kobakant.at/DIY/>.

⁶⁸ "Sonic Pi," <https://sonic-pi.net/>.

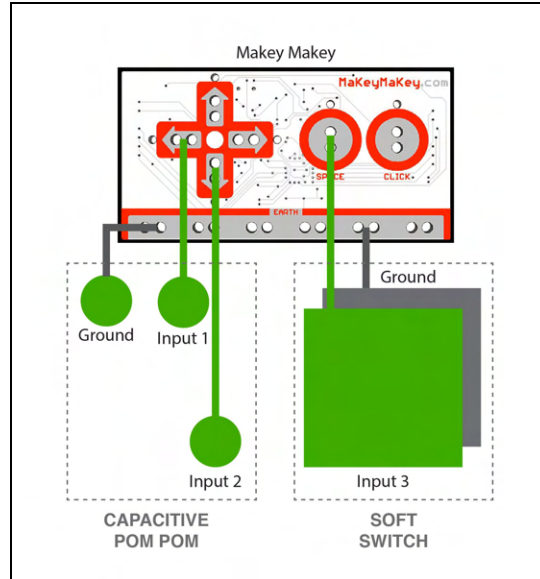


Fig. 41: *Grass Pad* setup.

4.1.2 Interaction Exploration with Sand and Pebbles

Another set of prototypes were built off from a research project I worked on at the Embodied Computations Lab.⁶⁹ I worked collaboratively on the *Sand Playground* project to produce a tangible interface that supports computational co-creative interactions on sand (see Fig. 42).⁷⁰

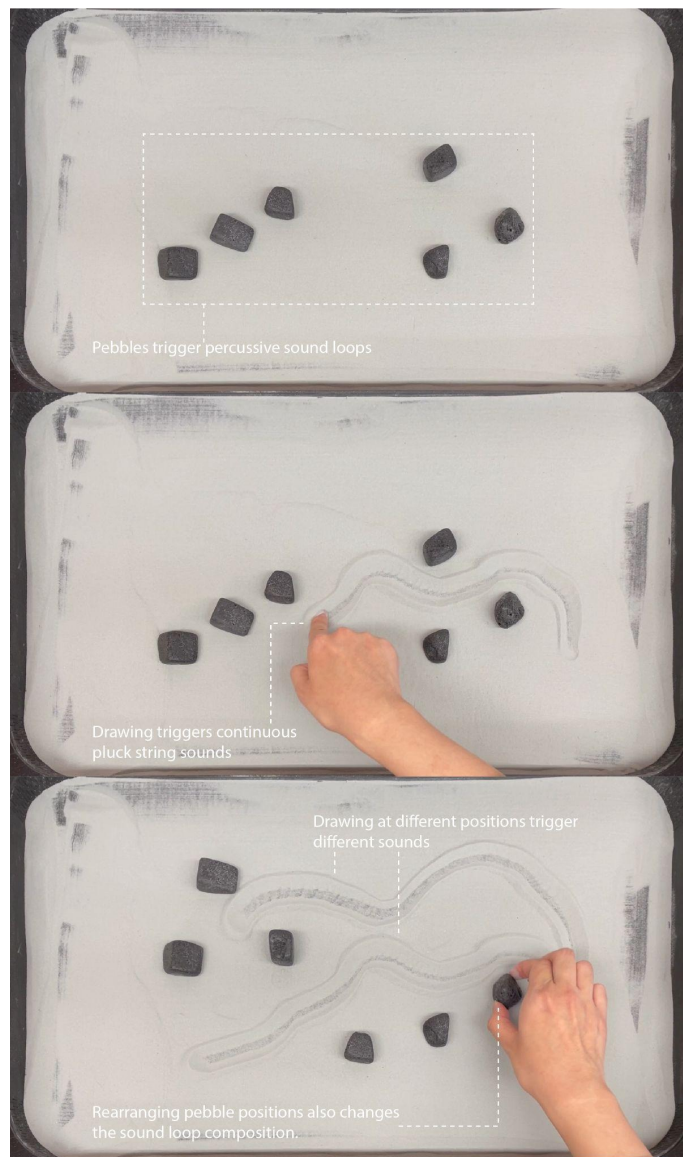


⁶⁹ Embodied Computations Lab. <https://embodiedcomputations.org/>

⁷⁰ Dina El Zanfaly, Yiwei Huang, and Yanwen Dong, "Sand Playground: Designing Human-AI physical Interface for Co-creation in Motion" (forthcoming)

Fig. 42: Physical setup for Sand Playground.⁷¹

Inspired by the usage of tracking hand drawing on sand for inputs from *Sand Playground*, I adapted and modified the detection mechanism from the project to build a sound making interface with sand and pebbles. By either drawing directly on sand or placing pebbles on to the sand bed, users can create sound loops and generate alternative sound sequences in real time by manipulating the composition on sand (see Fig. 43).



⁷¹ Dina El Zanfaly, Yiwei Huang, and Yanwen Dong, “Sand Playground: Designing Human-AI physical Interface for Co-creation in Motion” (forthcoming).

Fig. 43: Interacting with the *Sand Table*.

Pebbles are recognized and played as an ongoing sound loop of percussive sounds. I divided the sand bed into an 8x8 grid. The camera recognizes pebble positions and uses horizontal and vertical information for assigning sound individually. Each pebble is arranged sequentially into the loop based on their horizontal position. The vertical positions decide which sample from the 8 selected sounds should be assigned. Hand drawings are recognized as individual events and are played as pluck string sounds. The system tracks horizontal and vertical positions of the user's index finger to play a continuous sequence of notes and chords. Horizontal positions are mapped to notes between C3 and C5 (I used their corresponding MIDI number for mapping from 48-72). Vertical positions are mapped to chords of m6, m7, m9, m11 and m13 (see Fig. 44).

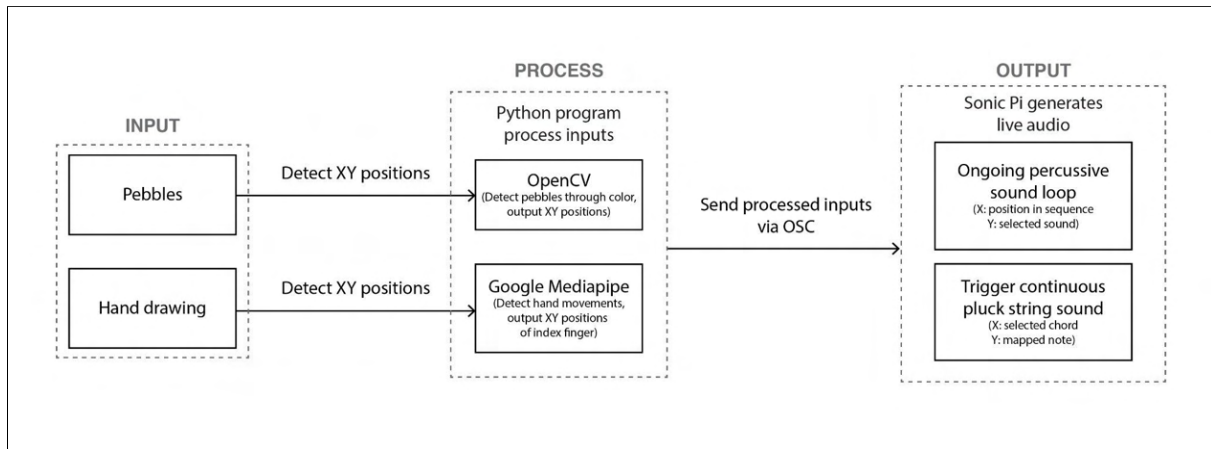


Fig. 44: Sand table interaction diagram.

For the hardware construction, I adapted and modified the detection setup from the *Sand Playground* project by using an Intel Realsense D435 camera to track the location of the user's hand. The recognition was processed by using the camera's RGB and Depth video stream with a Python program running OpenCV to detect pebbles and face locations and Google MediaPipe library to detect hand movements.⁷² The updated information was sent to Sonic Pi to trigger sounds via OSC.⁷³

⁷² "Google MediaPipe Hands." <https://google.github.io/mediapipe/solutions/hands.html>

⁷³ "Sonic Pi." <https://sonic-pi.net/>.

4.2 Evaluation

The initial evaluations were conducted through two sessions with the prototypes of the *Sand Table* and *Grass Pad*. The sessions were conducted with the purpose of evaluating how aspects of materiality and interaction, sensorial feedback, and social interaction were perceived through the interactive experience.

I recruited CMU graduate and undergraduate students as participants from the MSCD cohort and from the Objects of Play course in School of Art, with five participants for the sand table session, and another three for the grass pad session. There was no overlap of the groups of participants during the two sessions. All of the participants are students from the College of Fine Arts with experience in Art and Design. Age range between 18 years old and 32 years old.

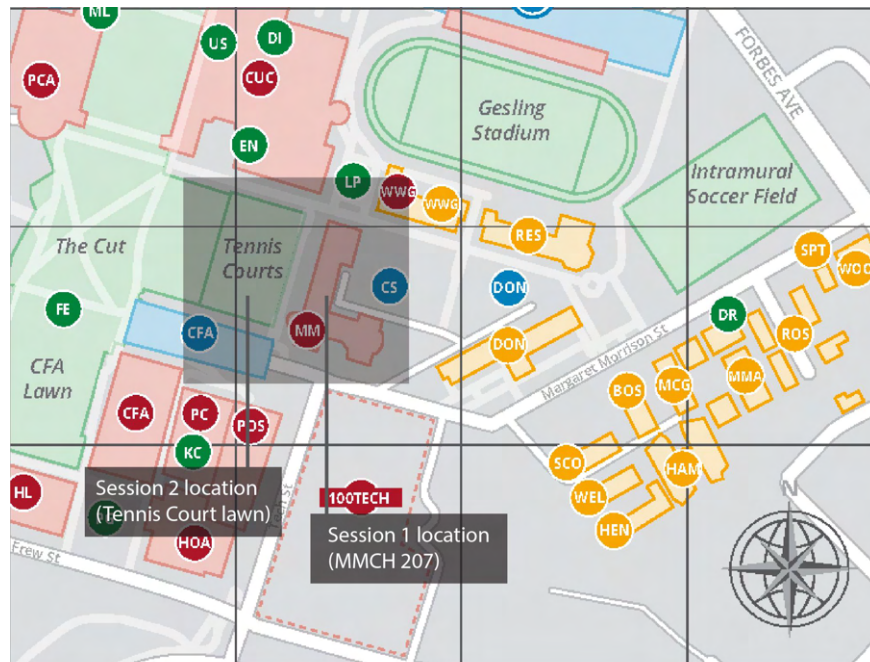


Fig. 45: Locations of the sessions annotated on CMU campus map (partial).⁷⁴

The prototypes were evaluated on the CMU campus in two separate sessions, with one group testing the *Sand Table* with an indoor lab setting in MMCH 207, and the other group using the *Grass Pad* at the Tennis Courts lawn (see Fig. 45). The first indoor session was conducted on April 25, 2022, and the second on May 1, 2022. The outdoor session was conducted on a sunny day with good weather conditions. Both sessions started with an introduction to the basic

⁷⁴ Maps. <https://www.cmu.edu/visit/maps-parking-transportation.html>

information on the task and how the interaction with each system works. Participants were asked to explore the interface casually in a playful manner. They could either explore the interface by themselves or interact with others at the same time. Throughout, they were asked to use a verbal think aloud protocol and speak aloud their observations, thoughts and decisions during the experiences. At the end of each session, I followed up with the participants with a series of open-ended questions that encouraged reflection on their experience with the interface. These questions probed their understanding of the interaction, their materiality and their perception of the sensorial experience, as well as gathered comments on the collaborative or collective engagement. To document participant interactions, I took photos, videos, and field notes to gather insights on participant behavior, record exploration of the interfaces, and to facilitate further reflection.

Materiality and Interaction

Participants had overall positive experiences on the tactile feedback of both *Sand Table* and *Grass Pad*. One participant commented on the *Sand Table* that: *“I like that drawing on sand triggers pluck sounds. It makes sense with the gesture, and also reminds me of how one would play the actual instrument.”* The experience creates a visual composition on sand and while many found the experience helpful to understanding and manipulating the sonic composition, some participants did suggest variation in the form, color and texture of the pebbles could be helpful : *“It might be interesting to use pebbles in different colors or shapes to add more to the entire drawing.”*

After getting familiar with the interface, I observed that the participants had different approaches and behaviors to building sound compositions in the sound. They experimented in different ways with the pebbles, their placement, and making marks with their hands in the sand. For example, some participants chose to create sound loops only by arranging, aligning and sequencing the pebbles (see Fig. 46).



Fig. 46: Participant aligning pebbles to create percussive only sound loops.

For the *Grass Pad*, participants were able to understand the interaction immediately. They instinctively explored the unusual material by touch and through this exploration, the participants discovered that the surface was interactive: *“my first impression (to interact with the Grass Pad) was to rub the surface.”* Based on this, one participant suggested an alternative way of interacting with the soft stroke sensors: *“so it would be nice to have sounds triggered by rubbing as well.”* This suggestion provides potential future improvements on adding stroke sensors to detect and react to similar actions and inputs as the capacitive sensor under the grass material.

Sensory and Multisensory experience

Participants appreciated the multisensory experience of the interfaces that combine tactile with sound composition: *“I really enjoy hearing the sound playing along when I draw on sand. It adds another layer to the drawing experience.”* Participants compared this multisensory combination to traditional sound composition. They viewed it as a valuable strategy to encourage people without professional knowledge or musical expertise to participate freely and playfully: *“The interaction is easy to understand, and I feel like I don’t need a great amount of musical or composing knowledge. I can just draw on sand to play sounds.”* This feedback suggests that a multisensory combination (in this case the involvement of touch and tactile feedback by drawing in the sand or arranging tangible stones with active listening to the unfolding sound composition) is useful. In particular, the tangible, manipulable objects and materials used in the sandtable

have many affordances in orchestrating an interactive sound experience casual and playful, leverages interaction methods that people are familiar with, and are materially rich and sensorial interfaces that encourage exploration and experimentation.

Social Interaction

The prototypes support multiple people interacting and co-creating sound together. I observed five (three participants during the *Sand Table* session, two during the grass pad session) trying to coordinate the sound composition with each other. This resulted in a collaborative experience (see Fig. 47 and 48). As depicted, *Sand Table* allowed two participants to work at either end of the table, to observe one another's actions, and to respond by adding or removing pebbles and by sketching in the sand. The act of collaboration was casual and in the form of exploration. During the process, participants tried to negotiate with the space when drawing on the sand bed together at the same time.

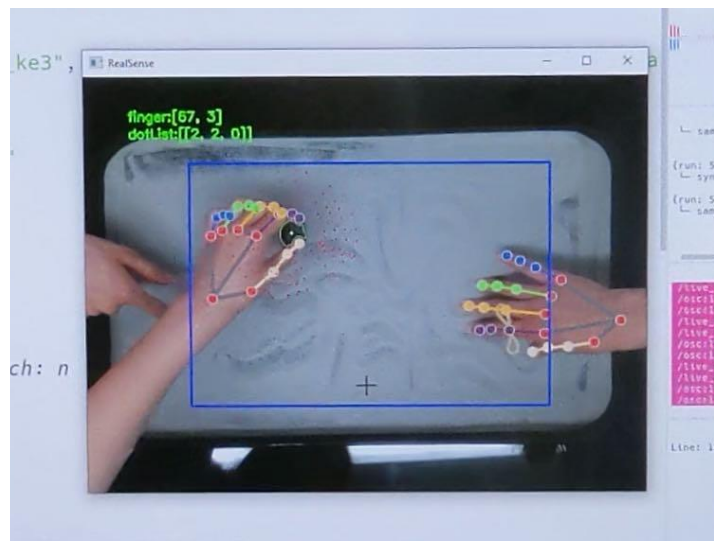


Fig. 47: Three participants drawing and placing pebbles together.

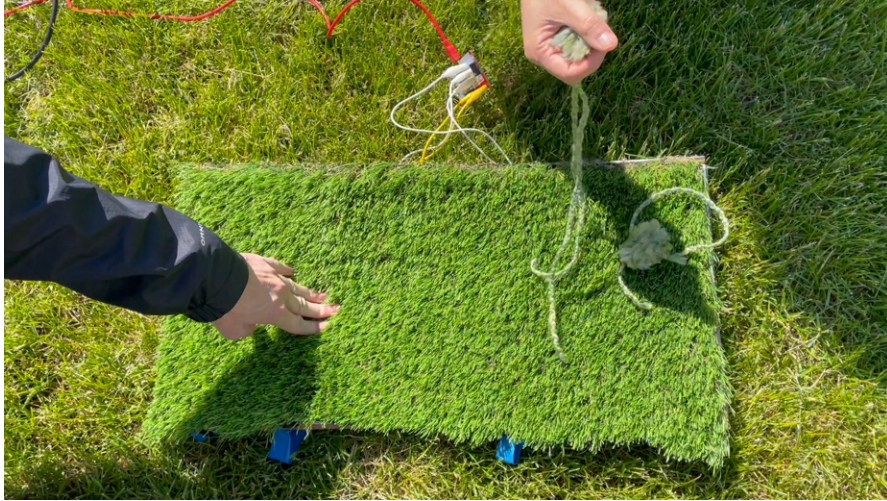


Fig. 48 : Two participants trying to collaborate using the Grass Pad.

For the Grass Pad prototype, since it was built at a small scale with just two types of inputs, participants approached and experienced individually at first, and attempted collaboration when I informed them it allows multiple users to interact. My assumption is that the limited number of inputs and scale restricted the variation of how participants can collaborate.

4.3 Limitations

As part of this work and the preliminary evaluation it is important to note a number of limitations that may affect the findings as reported.

Refining detection mechanism: I observed that due to the current setup, the camera would sometimes recognize dark spots as pebbles due to the color detection, and participants noticed the case and tried to experiment with their drawing paths (see Fig. 49). To still retain a playful and diverse experience but control the misusages, I intend to either change the base color of the sand bed or use different colored pebbles instead.

User group: The evaluation included eight participants: five used the *Sand Table* and three used the grass pad. The number of participants is small and participants did not use both interfaces. Thus, direct comparison of the participants' experience from indoor to outdoor can not be drawn. This can be an opportunity for future work.

Evaluative context: To facilitate the evaluation an on-campus public space was chosen. It was a substitute for the intended public plazas discussed in Section 3.2. The location shares many of the same characteristics as the plaza studied but has some differences as the location is close to academic buildings, has less green and natural space, etc. As such there may be differences in the findings if the prototypes were deployed to a plaza space.

Sensorial Experiences: As noted previously, this research does not address or explore the sense of smell and taste. This is because of the influence of the ongoing COVID-19 pandemic and the difficulties of exploring certain senses in public settings. Future work should address these limitations and explore potential opportunities on other senses.

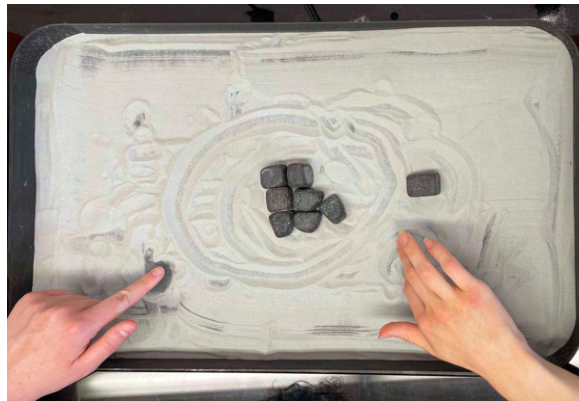


Fig. 49 : Two participants interacting with the sand interface, one trying to “trick” the system to detect the drawn dark spot as a pebble.

5. Discussion and Future Work

5.1 Discussion

This thesis utilizes computational methods to address the potential design opportunities of reshaping multisensory experience in public space. Below I present three takeaways that this thesis provides based on the design research conducted and the insights gathered from evaluating the prototypes.

5.1.1 Takeaway 1: Design Considerations

Beyond the contextual information and site-specific conditions of a public space, key elements that inform the sensorial interaction design for public spaces include: materiality, interactive experience, and the affordances for social engagement facilitated by the design. This thesis shows that the characteristics of a design material has a notable influence on the interaction. This is established by the insights gathered from the prototyping process and findings produced from the evaluation sessions. The interactive experience should be informed by the properties and qualities of the material and the sensorial feedback that it can produce. By evaluating the prototypes, I found that the qualities of unusual materials (e.g. the tactile experience of artificial grass or sand) tends to intrigue people to explore and to become more engaged in the interactive experience. To produce an effective multisensory combination (e.g. tactile and haptic paired with the acoustic), the choice of inputs and outputs in the system need to be closely associated with the material and with the senses that are being engaged.⁷⁵ To create potential for social interaction, this thesis notes the effectiveness of providing a casual, playful setting for users to interact freely with other people nearby.

5.1.2 Takeaway 2: Design Process

The research process of this thesis is heavily inspired by *the Street Life Project* and *Urban Probes* (see Section 2.1.2).^{76 77} The process began with on-site observation to produce an inquiry

⁷⁵ Barry E. Stein et al., “Semantic confusion regarding the development of multisensory integration: a practical solution” in *The European journal of neuroscience* vol. 31,10 (2010): 1713-20. doi:10.1111/j.1460-9568.2010.07206.x

⁷⁶ William H. Whyte, *The Social Life of Small Urban Spaces* (1980).

⁷⁷ E. Paulos, & Tom Jenkins, “Urban probes: encountering our emerging urban atmospheres”, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05)*.

into the observed human behaviors, the functions and role of public space, and the material conditions of the sites. In addition, the on-site observation helped to identify and uncover potential design opportunities. Using these insights, initial design prototypes were developed based on the observed phenomena and behaviors. Pilot deployments and reflections on preliminary evaluation with participants helped to find ways to refine and improve the prototypes. The design and prototyping process follow the style of rapid iterative prototyping to gain quick successive tests and essential feedback before moving towards more refined products. It is best to carry out an on-going process of identifying elements to improve, proposing prototypes, evaluating prototypes, and then going back again.

5.1.3 Takeaway 3: Evaluation with Participants

The initial evaluation sessions for the *Sand Table* and the *Grass Pad* (see Section 4.1.1 and 4.1.2) provides insights on how the testing environment and setup influences the experiences for participants. Since both of the prototypes involve sound production, it is necessary to calibrate the output sound level and address the relationship to and influence of ambient environmental sound in the experience, especially for outdoor spaces. Reflecting on the feedback from evaluation sessions, the materiality of the interface appears to have a constant and important observed influence on the experience, confirming the theory of material driven design proposed by Karana et al.⁷⁸ The prototypes produced throughout this thesis also explored a range of different ways to engage participants, including emphasizing an individual experience (grass bench), observing the collective behaviors and building participation with individuals (collective sound archive), and encouraging multiple users to interact together (*Sand Table* and *Grass Pad*). This thesis chose to focus on the last mode of engagement, but also acknowledges the different considerations for social engagement and the varied forms of social interaction in each approach. The modes of engagement should consider aspects including: potential participants, spatial characteristics, timespan of the project, and weather conditions. For future research and further exploration, a study and evaluation on comparing the different modes of social interaction should be considered.

⁷⁸ Elvin Karana et al., “Material driven design (MDD): A method to design for material experiences”, in *International Journal of Design* 9, 2: 35– 54 (2015).

5.2 Future Work

Reflecting on the feedback from evaluation sessions and the limitations noted in Section 4.3, future work will focus on creating versions of the two prototypes (the *Sand Table* and the *Grass Pad*) that operate at a larger scale and are better suited to an outdoor public space. I would also like to redesign the interactive inputs to work within an enlarged interface. This, for instance, would involve changing pebbles into larger objects, modifying the inputs with stroke sensors to recognize the act of rubbing the material's surface, and considering spatial considerations and ambient acoustic environment of the site, as well as how people operate in, behave and move in public space as influencing factors for the design.



Fig. 50 : Concepts for installing the prototypes in public spaces

Based on the on site observations conducted in September 2021 (see Section 3.2), I plan to redesign and deploy the prototypes in a public space in Pittsburgh, PA. The four sites that I've visited are the potential installation sites. These include the Agnes R. Katz Plaza, the Allegheny Riverfront Park, Point State Park and Schenley Plaza. Before an actual deployment in a public space, it would be important to conduct another round of site visits to help determine aspects of the deployment including: specific locations suitable for installation, possible technical

constraints (including: power support, depth camera installation, mounting and positioning, interface redesign, interaction structure and organization, etc.) in the spaces, ambient environmental conditions, and suitable times and durations to get most public participation with the interactive installations.

In addition, future work will involve a more robust and comparative evaluation of the prototypes. I plan to scale up the number of participants and to conduct on-site observations of how public audiences engage with, encounter and respond to the sensorial experience. These evaluations will use a similar format and workflow to those described in Section 4. They will include interactive experience sessions where people can explore the interfaces and experiences. After the session, they will be asked to fill out a brief questionnaire and an open-ended interview, semi-structured with guiding questions. The questionnaire will solicit feedback on: 1) the materiality and interaction of the installations; 2) multisensorial experience; and 3) social interaction in public spaces. I also plan to expand the evaluation of what types of social interaction are supported by the interfaces and how small groups coordinate sound composition and design. The full questionnaire and evaluation protocol for these next steps are included in the appendix.

6. Conclusion

This thesis provides a process of defining design considerations on prompting social interaction in public space through multisensory experiences. To establish contextual information, this thesis consults research and literature on study about life in public spaces, multisensory perception and experience, and sensory design practices, to generate principal aspects for producing design research inquiries. Based on the design considerations, I conducted on site observation and produced design prototypes of a series of multisensory interactive objects that utilizes computational methods to address the materiality and interaction of sensory experiences. I evaluated the two redesigned prototypes, *Sand Table* and *Grass Pad* through two sessions and reflected on the findings. The takeaways of the thesis include: design considerations (on material qualities, multisensory combination, and social interaction); proposed design process (observation — identifying design opportunities — producing and evaluating prototypes) and initial evaluation with participants. My next step for the research is to scale up the prototypes and deploy them in real spaces, as well as conduct another round of evaluation in public.

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Appendix - Evaluation Protocol and Questionnaire

Prompt and protocol

participants are encouraged to explore casually and playfully with the interface, and speak aloud their thought process on the decisions or actions during the experience.

Questionnaire

Materiality and interaction

1. Did the material characteristics (of the installation and the environment) affect your experience? How?
2. Did you notice any relationships between the materiality of the installation and the way of interacting with it?

Multisensorial experience

1. Are you aware of any multisensory experience? How did your senses influence each other?

Social interaction in public space

1. Did you interact by yourself or with others? Why?
2. Did you feel influenced by other people (if there were multiple users interacting at the same time)?