Sensing As World Noticing

Facilitating Practices with Ecological Data

Abigail Feldman

Department of Graphic and Industrial Design
College of Design | North Carolina State University
April 29th, 2021

Submitted in partial fulfillment for the degree of Master of Graphic Design

Helen Armstrong, Committee Chair,
Professor of Graphic Design

Scott Townsend, Committee Member,
Professor of Graphic Design

Matthew Peterson, Committee Member,
Assistant Professor of Graphic Design

Program Statement on the Master of Graphic Design Final Project

This document details a final project, which in design is commonly referred to as a graduate “thesis,” at North Carolina State University. The work was defined in a 3-credit course in a fall semester, and executed in a 6-credit course in the following spring semester. The Master of Graphic Design is a terminal professional degree with a research orientation, but like the MFA and MDes, it is not a primary research degree. This is a discovery-based investigation. Cash (2018) describes the process of building scientific knowledge as a cycle between theory building and theory testing. The theory building mode includes (1) discovery and description, (2) definition of variables and limitation of domain, and (3) relationship building (pp. 88–89). This investigation is restricted to the theory building mode. The theory testing mode includes (4) prediction, testing, and validation, and (5) extension and refinement (p. 89). While experts may have been consulted, this investigation does not entail any testing with human subjects, and it does not endeavor to prove anything; all assertions are tentative and speculative.

See: Cash, P. J. (2018). Developing theory-driven design research. Design Studies, 56, 84–119.

In an era of sustained ecological crisis, radical modes of eco-social relations are necessary. Casting a scientific gaze onto the natural world can foster respect, and with time, develop these relations by revealing the interconnected relationships of ecology to the human. As sensing technologies and the internet of things allow ecological data to be gathered and distributed, there are opportunities to make interactions with this data ontological. This investigation explores a range of potential acts of noticing with sensor-gathered data across a social internet of practices. By experiencing multi-modal interactions with ecological data that reflect the liveliness of the natural world, humans may develop closer affiliations with their multi-species communities.

Land Acknowledgment

The ecological community of living beings that this project engages with was stewarded by two Indigenous Nations: the Tuscarora and the Catawba. This ecology has also borne withness to hundreds of years of systemic mistreatment of African people and their descendents. The relationships of ecology are far-reaching and resonant. History is no different. The latter deeply influences the former, and I acknowledge that the history of this space has informed, disrupted, and severed the ecological relationships addressed in this investigation.

Gratitude

To Helen Armstrong, for planting the seeds that will continue to lead my design practice.

To Scott Townsend, for helping me articulate my voice.

To Matt Peterson, for accepting every panic email.

To my cohort, for solidarity through this process.

To Syashi, Gloria, and Anna, for being there from the beginning.

To my family, for instilling a deep respect for the natural world.

To the members of Special Collections, for your support, flexibility, and kindness.

To Lydia Waybright and Ben Jones, for never declining an invitation to my document.

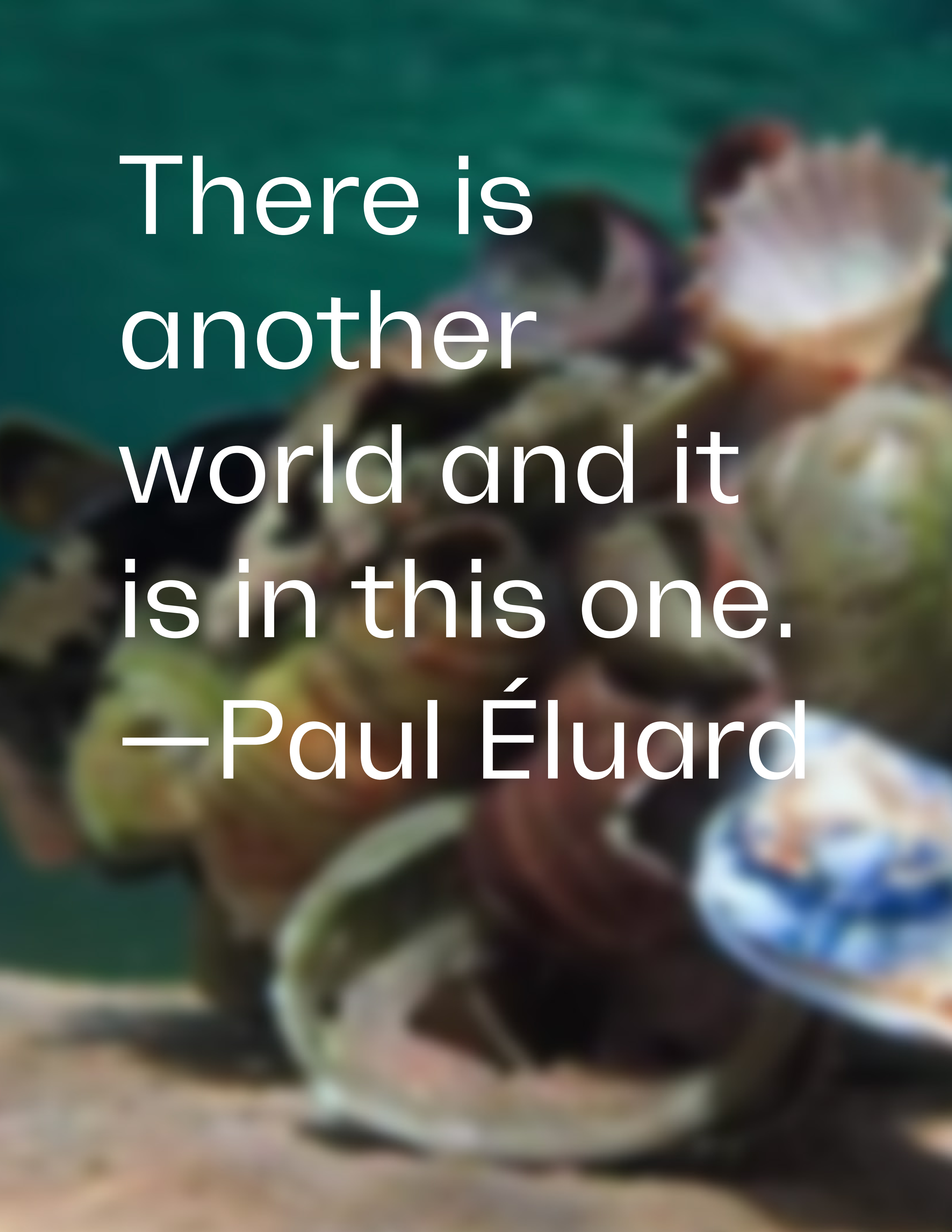
To Marcie, for your steadfast humanity, Eryn, for the ease of your presence, and Jack, for your blue jay activity.

To my teachers, most notably Christopher Vaughan, Daniel O'Malley, Kristen Lillvis, Jonathan Cox, Dr. Derek Ham, and Dr. Rodney Waschka, for broadening my view.

To my grandmother, Cecelia. All that I achieve is possible because of you.

To Torin, for your immense patience and unwavering encouragement. You made every moment lighter.

To the birds at my window, for your company.


There is another world and it is in this one.
—Paul Éluard

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Introduction

We find ourselves sitting in gradually boiling waters of an ongoing ecological crisis. Fires rage on the west coast of the United States, the sky glows orange, and clouds of smoke sweep hundreds of miles. Two hurricanes converge in one city at the same time. Permafrost in northern latitudes have begun to melt and frozen methane deposits are becoming increasingly vulnerable.

Progress is a human narrative that emphasizes the processes of industrialization and capitalism. Progress implies that we are moving forward, toward the future, but as the conditions of our planet become more precarious, the future becomes less certain. Consequently, the narrative of progress grows increasingly slippery. The ways of being and living that have grown out of this narrative rest on shaky ground. As disasters accumulate, and precarity diminishes our ability to look outward and forward, we must reorient our gaze to the present. While precarity grounds us in day-to-day functions, our attention can likewise be restored to the local and immediate. Rather than world-building, we might begin to take up the practice of world-noticing by engaging with what, and whom, is already here.

My Octopus Teacher is the story of a man who returned to his home on the coast of South Africa and began to swim every day, as he did in his youth (Ehrlich & Reed, 2020). During one foray, he encountered a young Octopus. Day after day he returned to her den, and with time and attention he began to notice patterns. In order to find her, he paid attention to specific diggings in the sand and slight changes in the algal patterns that she moved through. By watching her hunt and eat he learned that to catch a lobster she must throw herself over them, while to eat a mollusk, she must drill precisely into the apex of the shell to release venom on the abductor muscle. He discovered with wonder that when under attack by pajama sharks, she picked up nearly one hundred shells with her tentacles and wrapped them around her body to protect herself. Not only did his perception and understanding of the Octopus change, but he noted that as his empathy grew for her, his relationships with people did as well. She taught him that he was a part of their shared place.

Attention to other species in our shared environment reveals the richness of the living worlds among us. Our own immediate present may not be the coast of South Africa, but cities are likewise teeming with the livelihoods of numerous creatures like the Carolina Chickadees I often see resting on the telephone line across from my apartment. Through acts of noticing, just like the man in My Octopus Teacher, we might develop affiliation for and with other species in our shared environments. This affiliation, with sustained attention, breeds mutual care. Care itself is a radical tool of orientation. Care is recovery, reimagining, and reunion. Relations of care open the door to new ways of living, being, and maintaining hope in our day-to-day.

Figure 1.1
A screengrab of My Octopus Teacher that shows the octopus wrapping shells around herself as a protection from sharks.

Problem Space

2.1 Problem Statement

As the world faces the impacts of environmental breakdown daily, ecologies face a collective, ongoing disaster. While sudden disasters generate circumstances of immediacy in which communities become aware of each other and often develop a sense of belonging, these affordances can likewise build more resilient communities in the face of ongoing disaster (Solnit, 2010). In the context of ecological degradation, the affected communities consist of not only humans, but all members of multi-species communities. The collaborative survival of a community is deeply interdependent (Liu et al., 2018). It rests on the health of the intrinsic, complex relations we share with the nonhumans in our local ecologies. Collaborative survival requires multi-species flourishing; in order to enact it we must attend to and respect these relations. In many communities, human connection to these relationships has been severed through the dominance of technological solutionism, mass production, and increasing ecological breakdown (Haraway, 2016). To reconnect with our collective community, we must attend to the existing relationships with our other-than-human partners. Deep wonder and appreciation of these nonhumans are one means of developing relations of care. In turn, these acts become a form of repair (Mattern, 2018). Care and appreciation are not innate qualities, but they can be acquired through attention and practice. One method of practice is to utilize the scientific gaze to foster intimacy and respect by deepening understanding (Kimmerer, 2013).

Collaborative Survival: describes how our (human) ability to persist as a species is deeply entangled with and dependent upon the health of a multitude of other species. (Liu et al., 2018).

Nonhuman: in this study nonhuman refers to an animal, insect, plant, fungi, or other living species that is not human.

Over time, by attuning to the experiences of nonhumans, the surrounding world becomes livelier. We can connect, and in turn, recognize our place as one entity entangled in the intricate dance of a collective ecology (Odell, 2019).

Sensors: technology that detects and measures stimuli through a wide range of inputs including chemical, mechanical, and biological sources. The sensor assemblage typically involves using electronics and software to convert stimuli into electrical and digital signals (Gabrys, 2016).

Ecology: a community of organisms with interconnected relationships between each other and the unique local environment.

Sensing technologies that detect and measure ecosystem stimuli through a wide range of inputs provide a means for humans to cast scientific attention to these relationships By interacting with sensor-gathered data, humans can become attuned to the invisible or previously unnoticed activity around them. These interactions change in meaning as the human begins to not only view the data, but to seek it, gather it, and experience it in bodily ways. The act of sensing in which humans use tools to measure and seek data generates relations between the human and the space around them (Gabrys, 2016). Mimi Ọnụọha defines data as the things we measure and care about (Ọnụọha, 2018). Giving communities the means to measure the worlds around them empowers them to develop and define new relations of care through data. While the systems and effects of ecological breakdown may not be in the hands of communities–and may be irreversible–communities can still build meaningful multi-species relationships. As interaction becomes ontological, we can adequately mourn what is lost, and maintain hope by expanding our affiliations to include the nonhuman community.

2.2 Justification

Ubiquitous sensing technologies have the potential to change our understanding of ecology (Mayton et al., 2017). Sensor-gathered data is typically gathered in 1s and 0s that are usually translated to numerical measurements we can make sense of, and occasionally translated to visual forms. There lies an opportunity to make sensor-gathered data warm, intimate, and the source of new eco-social relations by making the experience of the data as rich as the lives of the ecology it represents. Jen Lui, Daragh Byrne, and Laura Devendorf provide a framework of tactics to guide design of wearable devices that extend the human body outward into the environment. The framework outlines engagement: shared physical experience of the environment, attunement: the ability to sense the livelihoods of the nonhuman collaborator, and expansion: the blurring of nature-culture divisions, as three different acts of noticing that bring the human into the environment (Liu et al., 2018). This framework provides a structure for designing interactions that extend the scientific gaze to a full body experience.

Internet of Things: a ubiquitous network of objects, sensors, and materials that are able to speak to each other via connection to the internet.

There are many different types of environmental data. Like ecology, data is relational. While the Internet of Things serves as a precedent for connecting disparate, data-gathering technologies, it is simply a technological infrastructure. It does not account for the complex socio-technical activity surrounding the interfaces involved. The Internet of Practices is a framework that suggests together, the technical possibilities of sensors, the social practices around them, and the documenting, sharing, and communicating of those practices influence habitus: the permanent internalization of the social order in the human body (Ludwig et al., 2019). There is an opportunity to design socio-technical practices around multi-species data gathered by sensors to expand the human perspective of community to include the nonhuman.

Practices: a process and performative view on social life: structures and institutions are realized through practices; practices are local and timely and they have histories (Ludwig et al., 2019).

2.3 Annotated Bibliography

Attention, Awareness, Perception

Awareness and attention shape humans' perception of the world around them. By bringing their attention to people, places, and things they were previously unaware of, designing for attention can shift or expand perception. Several other assertions from the literature follow. Despite the disconnection created by human exceptionalism and enabled by many technologies, human cognition and perception is dependent upon synchronicity with the natural world (Abrams, 2012). Human perception and the world are not discrete entities, but are enacted together through experience (Valera et al., 2016). If humans shift their attention within their surroundings to notice new and different details, they create an irreversible change in the enactment of their perception of those surroundings (Odell 2019). Awareness is a product and process that may be created through an interaction between agent and environment (Niemantsverdriet et al., 2019). This altered perception is not an end-state but a process of staying aware and responsive to support mutual evolution (Light and Shklovski, 2017).

Ontology: Ecological and Community Identity

Literature on ecological and community identity foreground possible modes of expanding affiliation. Designing on the border of the present and future calls for collective sense-making that aligns a community with its local context (Escobar, 2018). A community identity is developed through multiple dimensions including a member's perception of territorial and socio-cultural distinctiveness of the community, members' perception of their own affiliation, belonging, and connectedness to place and group, and members' perception of others' affiliation, belonging, and connectedness to place and group (Puddifoot, 1995). One mode for articulating these dimensions is through symbols that construct an inside/outside boundary of belonging (Cohen, 2013). Bioregionalism is a particular community system in which members associate through identification with the local environment. Members become members through close observation of the local environment (Berg, 1991). Community systems offer a sense of meaning, are upheld through day to day concentration, and may offer resiliency (Solnit, 2010). Design can play a role in community identification by constructing new ways in which humans can attend to their ecological space (Boehnert, 2018).

Multi-Species Entanglements

Designing toward human recognition of a multi-species community requires designing with, and for, the nonhumans within it. In the face of environmental crisis, de-centering the human allows designers to consider the role of nonhumans and to combine human-centered, participatory, and speculative design methods toward complex socio-technological assemblages (Forlano, 2016). De-centering the human makes space for the role of other species in these assemblages to be made visible and to become articulated in the design process (Gatto and McCardle, 2019). Taking on a multi-species ethnographic perspective helps humans understand the liveliness of trees and other beings that are typically perceived as objects. To engage in ethnography of other-than-human species is to regard them not as the "other" but as another. This practice flattens hierarchy and represents other species as relational beings with different values, perspectives, abilities, and practices. Applying a multi-species ethnography suggests that we are not only learning more about nonhumans, but learning from and with them. By equating the experience of the human and nonhuman, it builds relationships between them rather than structuring a binary opposition of nature and culture. Multi-species ethnography allows humanness to be redefined through relation to other beings (Ogden et al., 2013). Without a hierarchy that conceives of the human world and the natural world as totally separate, humans may be able to their place as a single partner in the work of living (Purdy, 2015).

Information Architecture

To make complex relationships within ecology sense-able, it is necessary to consult the literature on potential structures for information. Actor-Network theory posits that all that exists in the social and natural worlds is a shifting network of relationships (Latour, 2005). Animistic design offers an investigative framework that shapes those relationships as imaginative interactions toward an open-ended, conversational realm (Van Allen et al., 2013). Sensing technologies specifically heighten users' sensitivity to their relationships in the social and natural world (Kuznetsov and Paulos, 2010). Together, sensing technologies and imaginative approaches to interaction open up sensorial connections to ecological processes across spatial and temporal scales (Mayton et al., 2017). Computation, sensing, networking, and wireless technologies allow ecological information to be experienced in a way that alters users' perception to focus and extend their natural senses (Paradiso, 2018). Creative human-nonhuman relationships may be produced through this transmission by imbuing the information with the liveliness of the natural world (Van Allen et al., 2013).

Table 2.3.1
Annotated Bibliography organized by topic.

Attention, Awareness, Perception	The Spell of the Sensuous: Perception and Language in a More-Than-Human World	Abram, 2012
	Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants	Kimmerer, 2013
	Design for Existential Crisis in the Anthropocene Age	Light and Shklovski, 2017
	Design for Collaborative Survival: An Inquiry into Human-Fungi Relationships	Liu et al., 2018
	How to Do Nothing: Resisting the Attention Economy	Odell, 2019
	Designing for Awareness in Interactions with Shared Systems	Niemantsverdriet et al., 2019
	The Embodied Mind: Cognitive Science and Human Experience	Valera et al., 2016
Ontological and Ecological Identity	What is Bioregionalism?	Berg, 1991
	Posthuman, All Too Human: Towards a New Process Ontology	Braidotti, 2006
	Design, Ecology, Politics: Towards the Ecocene	Boehnert, 2018

	Symbolic Construction of Community	Cohen, 2013
	Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds	Escobar, 2018
	A Paradise Built in Hell: The Extraordinary Communities that Arise in Disaster	Solnit, 2010
	Ontological Designing	Willis, 2006
Multi-Species Entanglements	Nonanthropocentrism and the Nonhuman in Design: Possibilities for Designing New Forms of Engagement with and through Technology	DiSalvo and Lukens, 2011
	Decentering the Human in the Design of Collaborative Cities	Forlano, 2016
	Multispecies Design and Ethnographic Practice: Following Other-Than-Humans as a Mode of Exploring Environmental Issues	Gatto and McCardle, 2019
	Staying with the Trouble: Making Kin in the Chthulucene	Haraway, 2016
	Animals, Plants, People, and Things: A Review of Multispecies Ethnography	Ogden et al, 2013
	After Nature: A Politics for the Anthropocene	Purdy, 2015

	Navigating alternative framings of human-environment interactions: Variations on the theme of 'Finding Nemo'	Preiser, 2017
Information Architecture	Program Earth: Environmental Sensing Technology and the Makings of a Computational Planet	Gabrys, 2016
	Participatory Sensing in Public Spaces: Activating Urban Surfaces with Sensor Probes	Kuznetsov and Paulos, 2010
	Monitoring the Coastal Environment using Remote Sensing and GIS Techniques	Jiang, 2016
	Reassembling the Social: An Introduction to Actor-Network-Theory	Latour, 2005
	The Networked Sensory Landscape: Capturing and Experiencing Ecological Change Across Scales	Mayton et al., 2017
	Beyond Visualization–Vivid Frameworks for Ubiquitous Sensor Data.	Paradiso, 2018
	Underwater Internet of Things in Smart Ocean: System Architecture and Open Issues	Qiu et al., 2019
	AniThings: Animism and Heterogeneous Multiplicity	Van Allen et al., 2013

2.4 Definition of Terms

The following are defined to clarify terms as they apply and relate specifically to this investigation.

Attunement: an act of noticing where the human has the ability to sense the livelihoods of the nonhuman collaborator (Liu et al., 2018).

Collaborative Survival: describes how our (human) ability to persist as a species is deeply entangled with and dependent upon the health of a multitude of other species (Liu et al., 2018).

Ecology: a community of organisms with interconnected relationships between each other and the unique local environment.

Engagement: an act of noticing in which the human recognizes their shared physical experience of the environment (Liu et al., 2018).

Expansion: an act of noticing that blurs the nature-culture division (Liu et al., 2018).

Habitus: a framework that understands practices as the permanent internalization of the social order in the human body (Ludwig et al., 2019).

Interface: the site where multiple subjects or systems affect each other.

Internet of Things: a ubiquitous network of objects, sensors, and materials that are able to speak to each other via connection to the internet.

Multimodal: involving multiple forms of interaction including, but not limited to touch, haptic feedback, auditory, gustatory, visual, gesture, and orientation.

Mycelium: the network of fungal threads that absorbs nutrients and transmits information and energy to other fungi and occasionally trees.

Nonhuman: an animal, insect, plant, fungi, or other living species that is not human.

Ontological Design: a design discipline that suggests by designing objects, spaces, tools, and systems that create, direct, and shape human attitudes, behaviors, and responses, human ways of being and becoming are also designed.

Practices: a process and performative view on social life: structures and institutions are realized through practices; practices are local and timely and they have histories (Ludwig et al., 2019).

Sensors: technology that detects and measures stimuli through a wide range of inputs including chemical, mechanical, and biological sources. The sensor assemblage typically involves using electronics and software to convert stimuli into electrical and digital signals (Gabrys, 2016).

2.5 Assumptions and Limitations

ASSUMPTIONS

This investigation necessitates several assumptions. Firstly, I assume that a networked system of sensors, materials, and objects could be not only accessible to, but directed by, a grassroots organization of citizen scientists. I make the assumption that privacy would be a foundational part of this system; all data collection within it would be closed-loop and maintained by community members. I assume that human community members have a level of interest that meets the threshold of participation. I assume that it would be possible, legally, biologically, and ethically, for nonhuman species to participate in such a system. Further, I assume that their participation would not endanger them, significantly disturb their immediate environment, or disrupt their biological functioning.

While I assume the perceptual change facilitated by this theoretical system would alter the behavior of participants, it is not prescriptive, and does not attempt to delineate what the change would be nor how it would manifest.

LIMITATIONS

This investigation frames both humans and nonhumans as equal co-producers, but due to time constraints and lack of expertise, it will specifically focus on the humans' mediation of the interaction. A lack of biological expertise along with my inability to completely disengage from an anthropocentric view means that this investigation will inevitably represent other species in a manner that reduces their full experience and livelihoods.

Ecological communities are unique. As this investigation centers around the ecological community of Raleigh, North Carolina, some findings will remain specific to this space and may not be transferable.

This system would require human and nonhuman participation, however, the scope of this investigation will specifically focus on the interaction of the human. This exploration involves the nonhuman to the extent that their own data production and participation shape the human interaction.

While this investigation supposes that such interactions may expand humans' perception of their community and thereby acknowledges the potential for behavior change, it can not, and does not, undertake the complete dismantling and restructuring of modern society that may be necessary. However, by giving people the tools to measure and advocate for themselves, I humbly position this investigation as nothing more and nothing less than a seed.

2.6 Precedents

To foreground this project I analyzed a range of projects, experiences, processes, and speculations around grass-roots community technology, local environmental sensors, human and nonhuman mutualism, and networks of care.

Key findings from these precedents:

- Multi-species sensing gathers data otherwise inaccessible to humans.
- Inventive forms of data collection spark engagement.
- Sensing technologies give communities the agency to independently and collectively monitor local data.
- Tactile and sensory experiences help people understand abstract forms of data.
- Community participation can lead to regular interactions.
- Interactions with other-than-human data increase awareness and understanding of other species.
- Different kinds of sensors require different affordances. Some may be moved throughout an environment and some may function in a single location over an extended period of time.
- A kit of parts or suite of tools may serve the needs of a community better than a single tool.

Citizen Sense kits are social sensor technologies that allow users to crowdsource local environmental data on community monitored infrastructure. Participants understand local environmental conditions and events, and connect with their community to mobilize.

Tidmarsh Living Observatory (figure 2.6.1) is a wildlife sanctuary that has been outfitted with sensors by MIT's Responsive Environments group to make information about the sanctuary accessible to the public.

Smart dust (figure 2.6.2) were ambitiously conceived micro-scaled sensors that were imagined to drift in clouds or swarms and monitor environments.

Hydrocitizenship was a three year research project that facilitated collaborative activities like cultural mapping, water and sediment collection, and a hidden ecologies workshop with children. The project was an investigation toward the ways in which communities can live with each other and their environment in relation to water in a range of UK neighborhoods (Payne, 2017).

ListenTree (figure 2.6.3) was an audio haptic display that turned a tree into a living speaker to channel audio from a distant wetland.

Biobots (figure 2.6.4) may be used to map large areas made inaccessible by disasters. In this project cockroaches are outfitted with sensors and guided through a radio beacon from a drone. Data from the sensors can then be translated to create a map of the terrain.

Fwish (figure 2.6.5) is a grid interface of robotics buoys that monitor water quality, sense fish presence, and visualize information through colored LED lights. Its purpose is to collect and communicate real time data to the public about the water quality and fish activity.

OOZ is an interactive series of sites created by Natalie Jeremijenko for both humans and animals. The sites provide humans a set of actions, the animals provide reactions and these couplets add to a collective pool of observation. The system relies on complex sensorial equipment to attract, deter or illicit interaction from its animal compatriot.

Melbourne Mussel Choir (figure 2.6.6) is a project that connected hall effect sensors to mussels. These sensors monitored the opening and closing of mussel shells, and converted this data, which is also indicative of how much water the mussels filter, into sound. Human observers could experience the sound as a measure of pollutant exposure through the utilization of natural mussel behavior.

Hand-Substrate Interface (figure 2.6.7) is a glove embedded with sensors that can be used to detect information about substrate (soil, organic matter, etc.) that supports fungal growth (Liu et al., 2018)

Pigeon Blog (figure 2.6.8) was a collaboration between pigeons that, using sensing backpacks, collected data on air quality during their flights and humans that were able to access the data to understand the pollutants around them.

Spillcam was a webcam that enabled a public livestream of the BP oil spill.

James Reserve Ecological Study Area (figure 2.6.9) is a nature reserve focused on using ecological monitoring and sensing for research. Data from the monitoring technologies are accessible to the public via the internet.

Interspecies Internet is a conceptual collaboration between Vint Cerf, Diana Reiss, Peter Gabriel, and Neil Gershenfeld around the idea of a multi-species Internet of Things.

Crittercam (figure 2.6.10) was a National Geographic project that attached video cameras and other sensors to wild animals to provide insight into their lives.

Elephant Seal Weather Tracker (figure 2.6.11) was a project that used location and environmental data gathered by sensors attached to elephant seals to predict climate change related weather and understand the elephant seals' response to it.

Animal Messaging Service (figure 2.6.12) was a speculative system for sending digital messages via migrating animals implanted with RFID tags.

Atlas of Community Based Monitoring & Indigenous Knowledge in a Changing Arctic (figure 2.6.13) is a platform that documents various community approaches toward the monitoring and documentation of environmental and social phenomena.

Pika Alarm was an installation that projected the call of the pika, an animal extremely sensitive to the effect of temperature fluctuation on their habitat, as a warning and call to action.

Exchange for Local Observations and Knowledge of the Arctic: a platform that partners with communities to create and distribute products that facilitate the collection, preservation, exchange, and use of local observations and Indigenous Knowledge of the Arctic.

The Illustrated Almanac of the Illawarra and Beyond (figure 2.6.14) uses the structure of the Chinese almanac to explore the rituals and rhythms of seasons. It shows the entangled time spans of multiple species.

FieldKits (figure 2.5.15) are sensing kits that allow citizen scientists to gather and share data on the FieldKit platform.

Figure 2.6.1
A synthetic creature created using Tidmarsh sensor data.

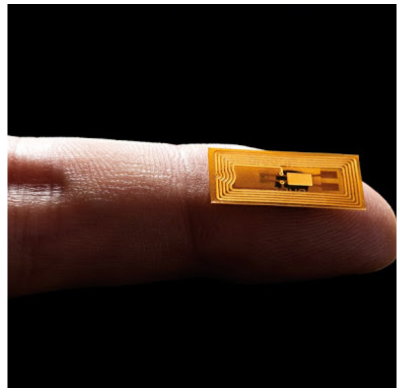


Figure 2.6.2
A SmartDust particle.

Figure 2.6.3
Humans experiencing distant wetland audio through a tree.

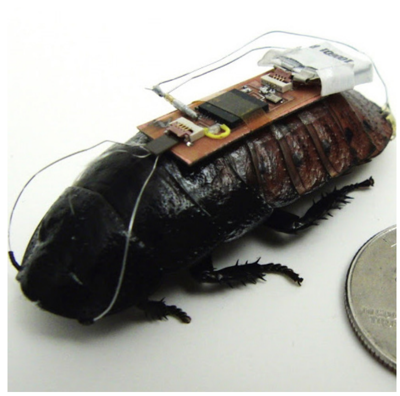


Figure 2.6.4
A biobot capable of traversing terrain inaccessible to humans.

Figure 2.6.5
A rendering of the Fwish Interface at the site of the fish interaction.

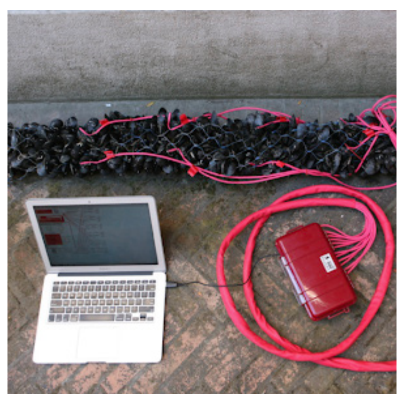


Figure 2.6.6
The Melbourne Mussel Choir made audible through sensors.

Figure 2.6.7
Hand-substrate interface measuring soil.

Figure 2.6.8
A PigeonBlog pigeon equipped with a sensing backpack.

Figure 2.6.9
Cameras at the James Reserve Ecological Study Area.

Figure 2.6.10
A sea turtle outfitted with a crittercam.

Figure 2.6.11
A group of elephant seals who will gather environmental data.

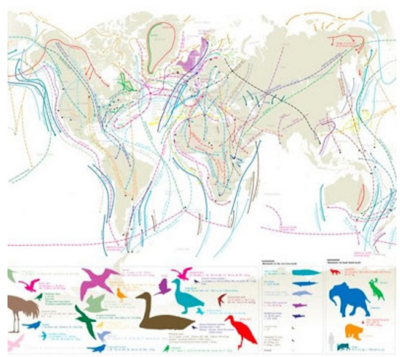


Figure 2.6.12
A diagram of the speculative animal messaging system.

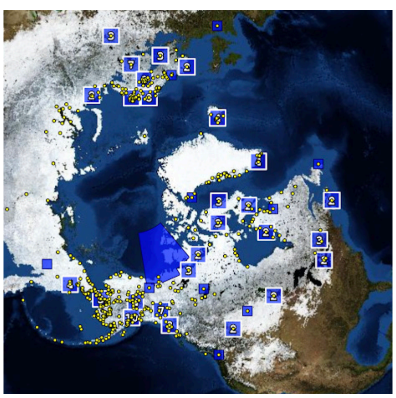
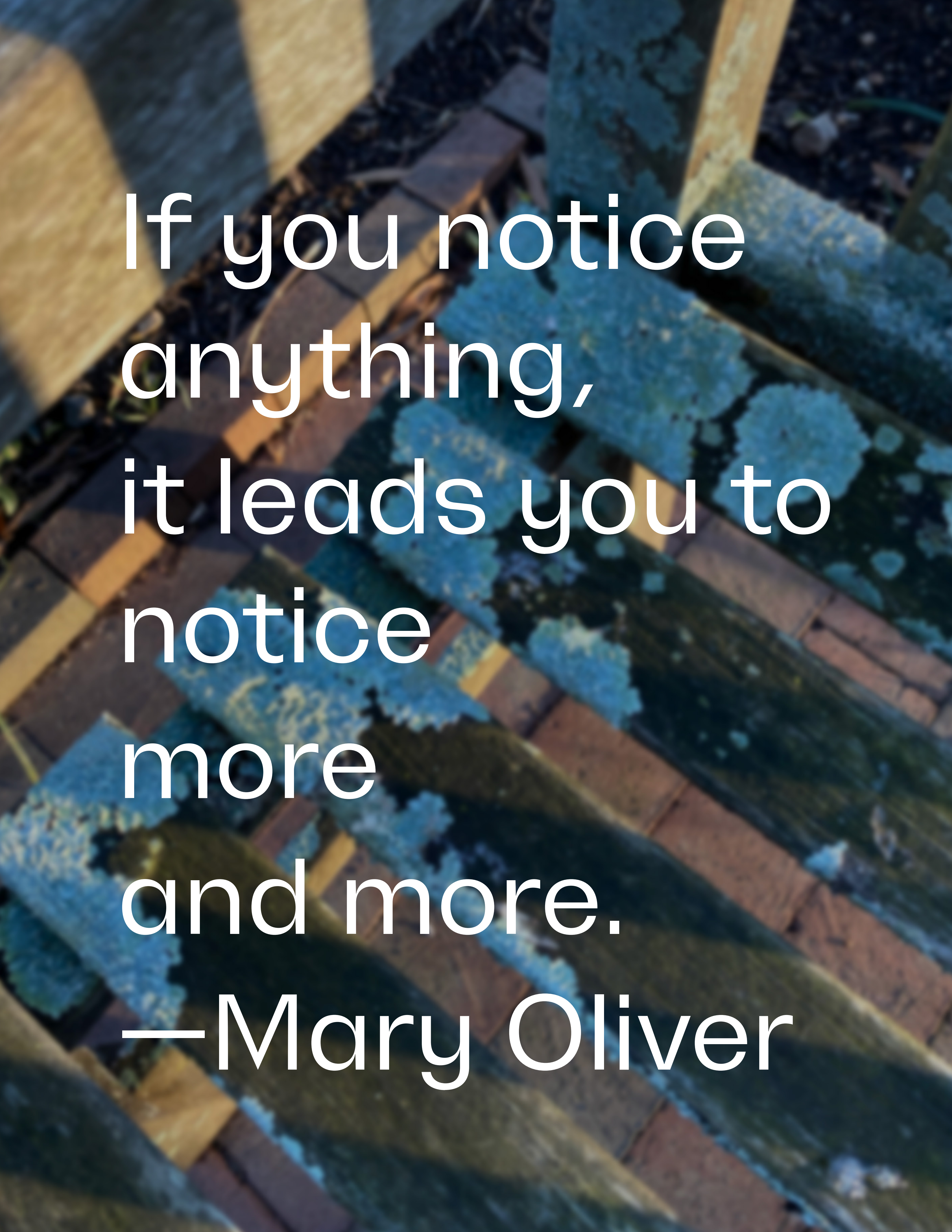


Figure 2.6.13
The Atlas of Community Based Monitoring.

Figure 2.6.14
The Illustrated Almanac of Illawarra and Beyond.

Figure 2.6.15
FieldKit sensing technology.


If you notice
anything,
it leads you to
notice
more
and more.
—Mary Oliver

Investigation Plan

3.1 Conceptual Framework

Figure 3.1.1
The three Acts of Noticing (Liu et al., 2018).

ACTS OF NOTICING

Acts of noticing (Figure 3.1.1) is a model of various forms of human involvement with nonhuman beings through experienced through interactions. The stages: engagement, attunement, and expansion, emerged from a study that reimagines human-fungi relationships and serve as a method of facilitating awareness connected to collaborative survival (Liu et al., 2018).

ACTOR NETWORK THEORY

Actor-Network Theory structures all objects, humans, nonhumans, and tools, as entities with equal agency that form networks or assemblages. Nature and society are produced through mediation of all requisite entities in a given network (Latour, 2005).

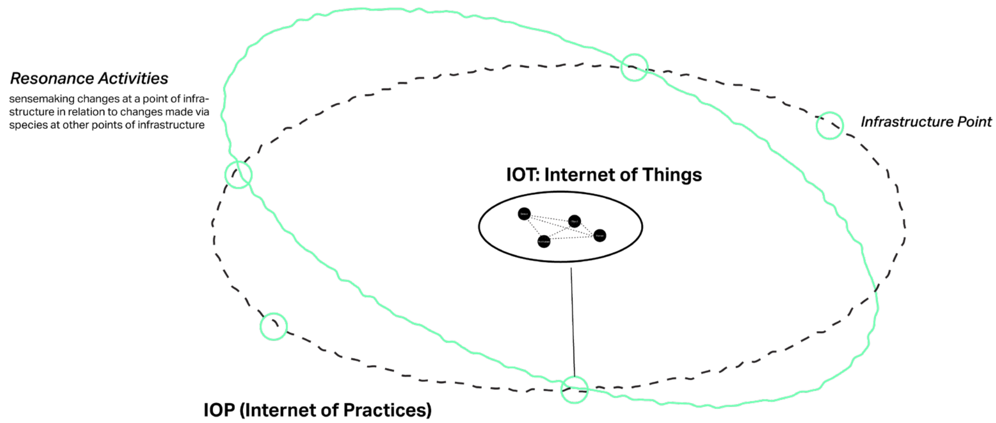


Figure 3.1.2
The Internet of Practices framework (Ludwig et al., 2019).

INTERNET OF PRACTICES

The Internet of Practices framework posits that sensors integrated into social practices act on how people perceive their own social organizations. Sensing technology modifies our perception, which in turn, alters the way we interact with the technology. Together, sensors and social practices become co-producers of habitus. (Ludwig et al., 2019).

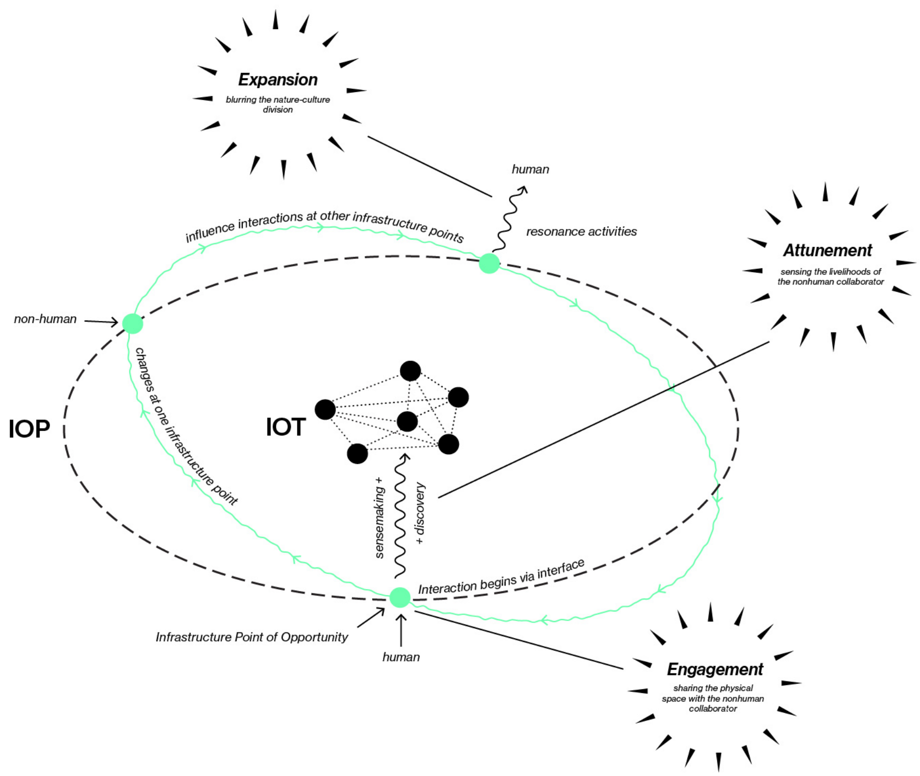


Figure 3.1.3
A conceptual framework synthesizing Actor-Network theory, Internet of Practices, and Acts of Noticing.

SYNTHESIS

The Conceptual Framework positions the acts of noticing as stages within a social internet of practices. Engagement takes place when the human encounters an interface. The interface is the meeting place between social and technological systems. Here, the human becomes aware that they are sharing the physical space with the nonhuman. The human participates in the act of attunement through their experience of data at the interface. The data enables them to sense the livelihood of the nonhuman. Expansion takes place through 'resonance activities,' or interactions that incorporate data from other physical locations in the system. This framework represents technology, humans, and nonhumans as equal actors in interactions.

3.2 Research Questions

My investigation is directed by an overarching research question with three subquestions that narrow and operationalize the exploratory design studies.

How can the design of a multimodal multi-species sensing network in urban environments facilitate acts of noticing between humans and their non-human collaborators, thereby shifting the humans' perception of their own ecological identity?

Engagement

Subquestion 1
How can an interface situate itself in, and adjacent to, humans' practices to engage the human in an interaction with the nonhuman?

Attunement

Subquestion 2
How can a data presentation highlight patterns and aggregations of data to attune human participants to changes in the lifecycle of the nonhuman collaborator?

Expansion

Subquestion 3
How can the interaction options change in relation to the experiences of others' interactions at different points in the system to foster a sense of community interdependence in human participants?

3.3 Investigation Model

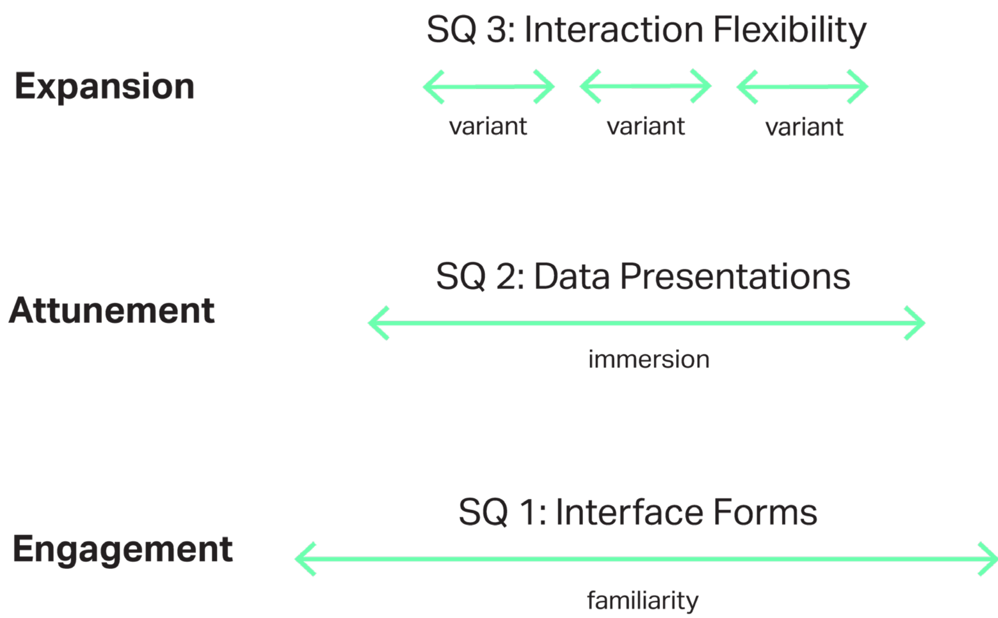


Figure 3.3.1
The investigation model positions subquestions across dimensions of familiarity, immersion, and change.

Subquestions 1, 2, and 3 each explore one of the acts of noticing stages: engagement, attunement, and expansion. Subquestion 1 studies will investigate interface forms across the dimension of familiarity. Familiarity refers to the nature of the interaction itself and how habitual or naturally it occurs to a person (Liu et al., 2018). Subquestion 2 studies will survey data presentations varying in scope. Scope is the level of focus, human attention and sensory engagement, or the degree of immersion (Liu et al., 2018). Subquestion 3 will explore how findings from subquestion 2 studies may vary under changing conditions across the connected system.

3.4 Scenario

Sheila

SHEILA: PERSONA

Sheila is a 47 year-old high school math teacher and single mother living in North Raleigh, North Carolina. She has an 11 year old daughter. Through her experience as a teacher and mother she has developed a high level of empathy and awareness. These translate to her relationships with other living beings as she is an avid birdwatcher. She believes it is important for her to instill these values in her daughter.

SHEILA: SCENARIO:

Sheila sees she has received an email from her local bird watching chapter about a new citizen science group forming in Raleigh. She joins the group and signs her daughter up as well.

PAIN + OPPORTUNITY POINTS

- Shared interactions could help her develop her daughter's relationship with the nonhuman.
- Monitoring technologies may provide insight relevant to her birding activity.

ISABELLA: PERSONA

Isabella is a 19 year-old first generation college student at NC State in Raleigh, North Carolina. She lives with her 23 year-old sister who is a full-time waitress. As a first-generation college student who grew up in a lower income household with less access and knowledge of technology, Isabella sometimes feels out of touch with her peers. During the Covid-19 pandemic, she and her sister started taking daily walks, varying from the greenway near their apartment to the local neighborhood. As the world has re-opened, the sisters have maintained their habit of walking together after working and doing schoolwork and have developed a higher level of awareness and familiarity of their surroundings. Isabella has started migrating outside more frequently during the day, bringing her schoolwork with her.

ISABELLA: SCENARIO

While Isabella has started to enjoy doing her homework outside, she and her sister share a desktop computer, so while she looks forward to going outside in the afternoon, she must spend her morning completing her online homework assignments at their desk inside. In the afternoon, she takes her notebooks to one of the small nearby parks to study. She spends several hours here, noticing the presence of the birds and enjoying her time amongst them. While on her way home from the park, she takes an alternative route and notices that a large oak tree along the path is dead. She feels a sense of grief, but doesn't know how to process it, or even what could be an appropriate way to honor the loss of life. Later, while walking with her sister, Isabella brings her to the tree. Together they wonder what could have happened to it.

Later that night, while searching online about local trees she finds a webpage for Raleigh's community eco-sensing group, and signs up.

PAIN + OPPORTUNITY POINTS

- There is potential for information to be conveyed while she has to be indoors.
- Sensor-data could inform her of unknown factors like a questionable air quality level while she is at the park.
- Interaction can act as a form of acknowledgment for events like the death of the tree.
- There is opportunity to fuel her curiosity while near other living beings.

Everett

EVERETT: PERSONA

Everett is a 28 year-old living and working in downtown Raleigh. He works in a high pressure, time consuming job, and spends most of his free time at happy hours with either coworkers or friends. As a result he is very burnt out and feels the need for a reset or reallocation of his time. Everett's activities and energy level lead to a very low level of awareness and empathy, while his work has given him a relatively high level understanding of technology.

EVERETT: SCENARIO

It usually takes Everett 20 minutes to walk from his apartment to his office downtown. During that time, he pays attention to environmental cues and occasionally listens to music, but it is mostly on autopilot. At work, he has a deadline coming up, and spends long hours working under a high level of stress. When he gets out of the office, he typically has cocktails with his friends at the bar a few blocks away, but he feels tired of the work-drinks-home routine, and texts his group message to suggest they do something else. They collaboratively search for other things going on downtown that night, and find the Museum of Natural Science's BugFest. They decide it will be a fun change from their monotonous routine, and meet there after work. At Bugfest, Everett learns from a vendor that the flies he always sees at the garbage outside his apartment are actually aiding in the decomposition process. Everett feels intrigued, and the vendor suggests that if Everett finds it interesting he should sign up for Raleigh's community eco-sensing group initiative. Everett feels energized by the night's activity, and signs up as soon as he gets home.

PAIN + OPPORTUNITY POINTS

- He feels bored and burnt out by his routine.
- He is intrigued by the idea of a new community activity.
- Walking to work provides an opportunity for him to interact with his environment in a new way.
- A sense of connection to something outside of work may ease his stress.

Studies

4.1 Engagement: Seeking the Site

How can an interface situate itself in, and adjacent to, humans' practices to engage the human in an interaction with the nonhuman?

APPROACH

An interface is not a device, but a site where human interactions with the environment and other intelligences are mediated (Brain, 2016). The interface between two subjects or systems is the area in which they affect each other. This study assessed the potential contexts and practices interfaces could be situated within to act as the site of engagement between the human and the nonhuman. Context in this case was defined as when and where the interaction would take place in relation to typical human practices in the urban environment. The design of this element explored how closely the interface was integrated into the space and place of humans' daily routines. Human practices refer to the enactment of knowledge and action in an interaction (Ludwig et al., 2019) To explore practices as a design element I analyzed the modes of action commonly used to interact with everyday objects and interfaces and determined where to mimic or deviate. I developed a matrix to structure interface design explorations by addressing variations in familiarity across both context and practice (figure 4.1.1).

PROCESS

During the early research phase of this study I conducted ethnographic observations to note convergences between the natural and built world in an urban environment as intuitive spaces for an interface to mediate between the human and nonhuman, shown in figure 4.1.2. Explorations in figures 4.1.3, 4.1.4, and 4.1.12 imagined interfaces directly in these convergences: lichens growing on built surfaces, human technology being integrated with trees, and birds landing and resting on city infrastructure. While exploration 4.1.3 maintained a similar form as what already existed

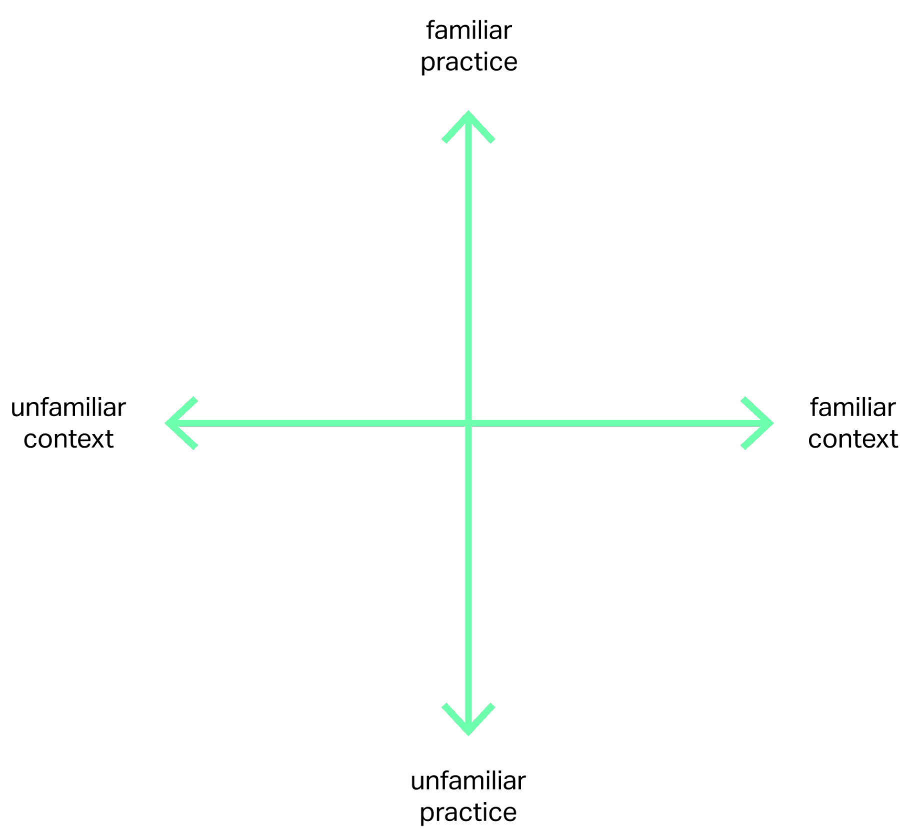


Figure 4.1.1
An investigation matrix that addresses variations in familiarity.

in the environment, explorations 4.1.4 and 4.1.12 reimagined contemporary urban infrastructure as sensor laden and intelligent: the railing of a walkway becomes haptic, and an ordinary stone becomes a display of information. The shared space that the interfaces inhabited remained a familiar site of daily human activity, but as those familiar surfaces initiated different visual and haptic interactions, the practices at those sites became strange and unfamiliar, thereby shifting the humans' perception of that seemingly familiar space.

Moving forward I interviewed an expert in close nonhuman interactions and observations: a local park ranger, nature photographer, and avid birder who regularly leads bird walks at the North Carolina Museum of Art. She expressed that birders find joy in the ability to capture and store their personal findings. Figures 4.1.8 and 4.1.14 account for how the user would be able to capture their personal data in the system both through a unique ID associated with their personal device and activated by a beacon at the site of the interface, and by documenting audio and visual data on their own while away from the interface. The importance of storing personal data suggested some form of an archive. Figure 4.1.9 proposes an archive as a multimodal heirloom that alters users' relationships with the nonhuman data, and by extension, the nonhuman, by extending the lifespan of the data beyond the moment. This form of interaction suggests to the user that information about local nonhumans is of personal significance.

Multimodal: involving multiple forms of interaction including, but not limited to touch, haptic feedback, auditory, gustatory, visual, gesture, and orientation.

The park ranger also noted that birders typically start by noticing what is in their immediate environment, around their home, and then expand outward. She identified that attaining a greater depth of information requires that users stay still and spend time. I applied these findings to the study, shown by figure 4.1.7, by bringing the interface into the home. In this case, a familiar context and practice allows the user to bring their full attention to the live data happening around them. In figure 4.1.5 I explored an extended interaction over time as a means of not only learning more about the nonhuman, but partaking in their experience. In this case, the user lays in a hammock-like interface made with haptic material that transmits a haptic interaction along seams of the interface that mirrors the electric signals exchanged between the roots of the trees the interface is connected to. The extended interaction mimics their very slow activity and allows the human to experience the timescale of the trees.

In Braiding Sweetgrass, Robin Wall Kimmerer describes the annual destruction humans unknowingly wreak when they cross salamander breeding grounds, flattening them as they drive down the road where unbeknownst to them, salamanders following the geomagnetic currents of the earth, cross their path. Figure 4.1.10 proposes an interface that addresses this specific scenario by integrating data about the paths of salamanders and human navigational data to point to the physical overlap as the human approaches it. Beyond this specific context, the notion of revealing unknown nonhuman data points the human to further contexts they are unaware of. Figure 4.1.11 does this by playing to the affordances of a public installation. Here users expect the unfamiliar or unknown. Curiosity is piqued with large scale visual stimulation, and as with a large scale art installation, users can have an ambient or close interaction. The ambient interaction provides a general interpretation that can be talked about and shared by a larger group of community members, while close, personal interactions may be more internal and provocative. In these interactions, the interpretation of the data involves a single user's memories, direct haptic engagement with the space, and idiosyncrasies that the experience might remind them of. These interactions make the data feel personally valuable. In figure 4.1.6 the overlay acts as a surface that displays the otherwise invisible data that relates to the electrical signals transmitted among the mycelium. The cutouts allow the human to touch the soil beneath them and simultaneously view the resonant effect on the mycelium on the overlay. This interface gives perceptible form to the relationship between the human and nonhuman. The interactions between something otherwise alien becomes tangible, visible, and immediate.

Mycelium: the network of fungal threads that absorbs nutrients and transmits information and energy to other fungi and occasionally trees.

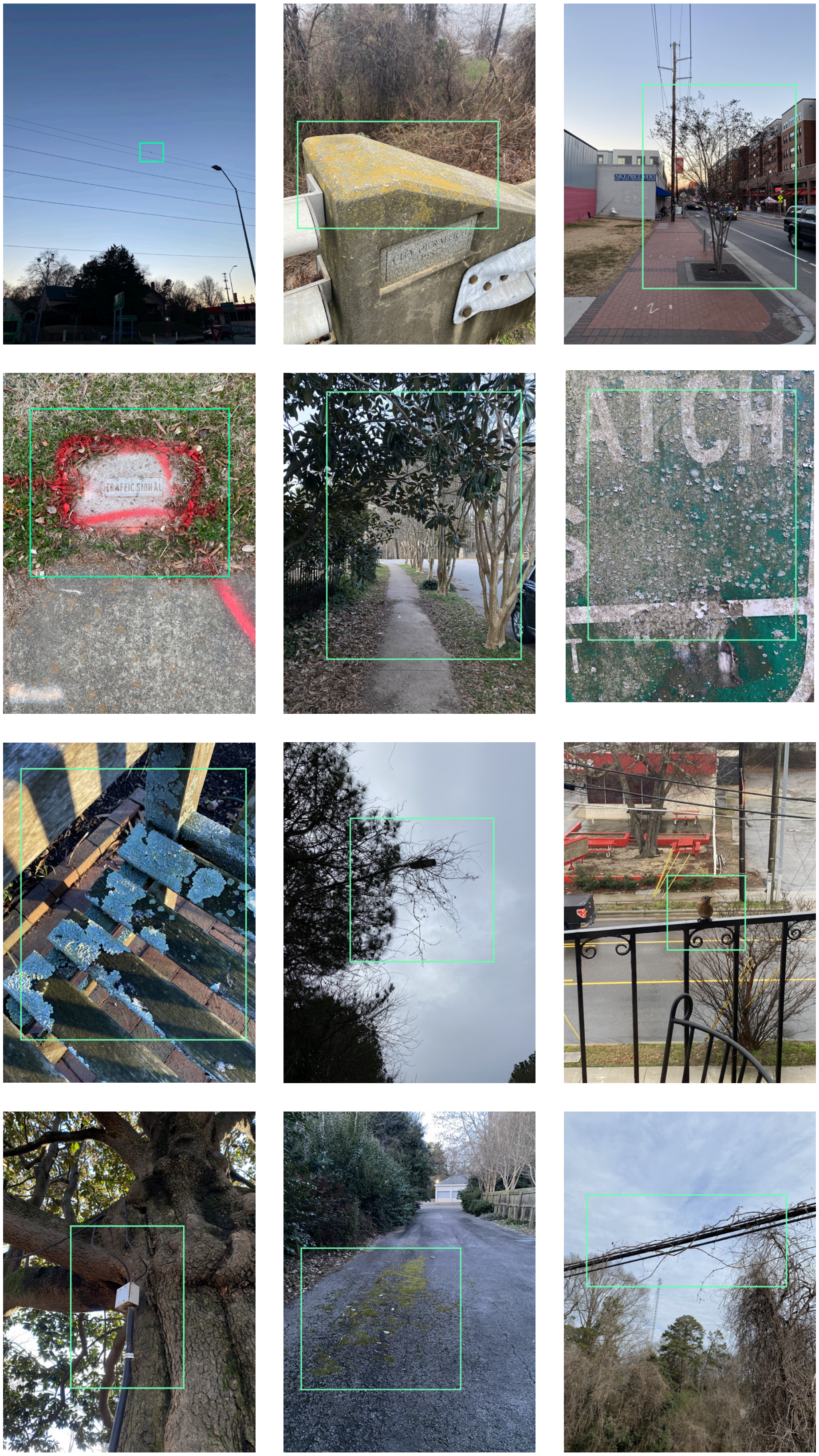


Figure 4.1.2
Multi-species ethnographic observations of convergences of the natural and built worlds.

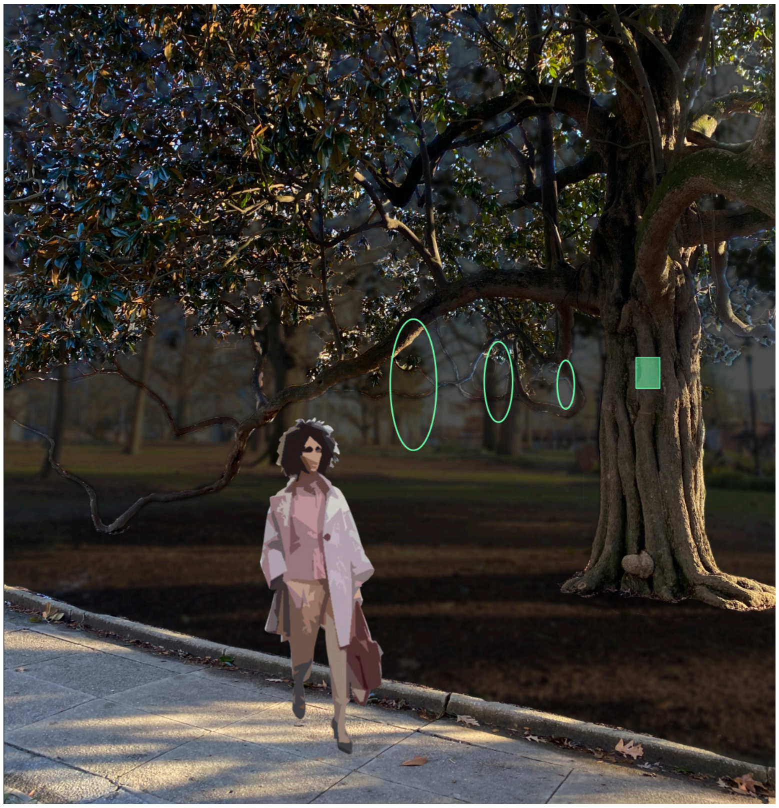


Figure 4.1.3
A tree with audio output activated by human presence.

VIEW ANIMATION:

https://college.
design.ncsu.edu/
thenfinally/feldman/
audiotree.gif

Figure 4.1.4
A haptic railing that generates interactions based on the presence of birds.

VIEW ANIMATION:

https://college.
design.ncsu.edu/
thenfinally/feldman/
hapticrailing.gif

Figure 4.1.5
A hammock-like interface with haptic technology built into the material. Sensors gather data on the electric pulses transmitted between the roots of the trees the interface is connected to. This transmission is mirrored across the haptic fabric of the interface and felt by the user.

Figure 4.1.6
A screen overlay that visualizes data collected by sensors located in the soil below. These sensors detect the electric signals transmitted through the mycelium. The screen includes cutouts where users can reach down to the earth beneath them and watch the impact of their touch on the overlay.

Figure 4.1.7
A window interface that uses machine learning to identify and highlight birds in the environment. Images are captured so that the human can see past footage.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/windowoverlay.gif

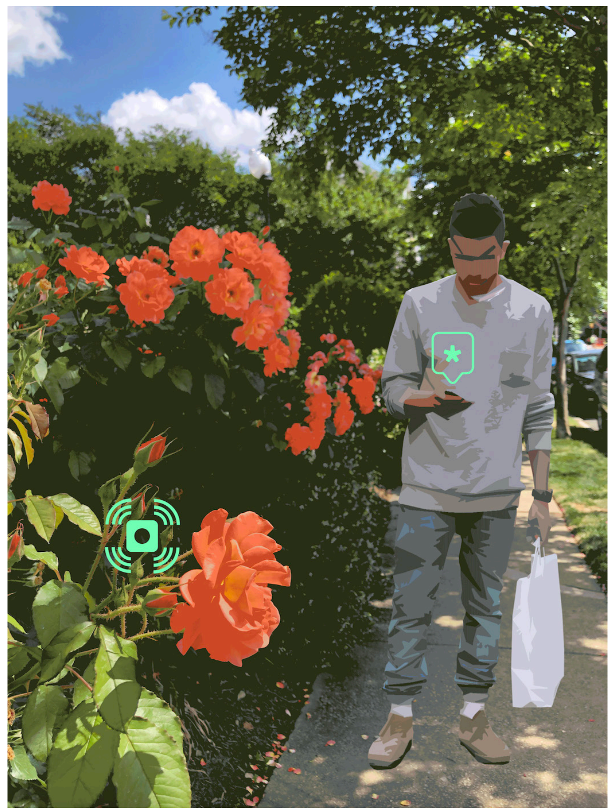


Figure 4.1.8
Humans are alerted to present system interfaces via beacons.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/beaconnotification.gif

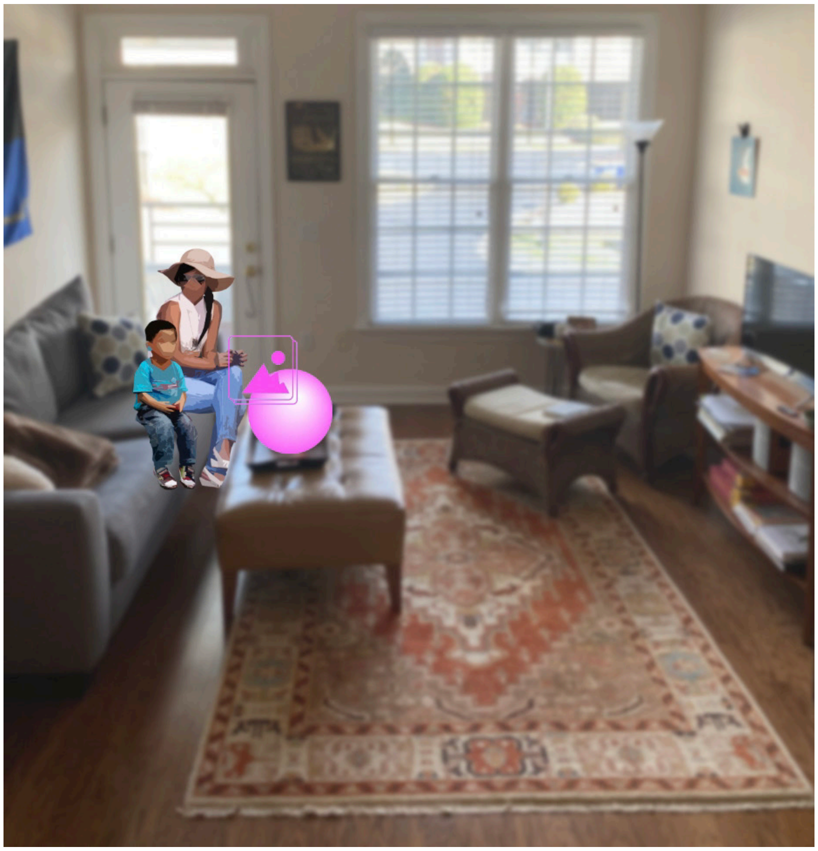


Figure 4.1.9
An in-home interface that displays all of the data associated with a household. It facilitates close and ambient audio and visual interactions.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/heirloominterface.mp4

Figure 4.1.10
A screen overlay that visualizes data collected by sensors below that detect the electric signal transmitted through the mycelium. The screen includes cutouts where users can reach down to the earth beneath them.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/salamandergis.gif

Figure 4.1.11
An interface that conveys data as a public installation.

Figure 4.1.13
A 3d model of the stone interface.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/stoneinterfacesurface.mov

Figure 4.1.12
An interface with embedded sensors that allows lichens to grow on the surface while capturing data about them and archiving their traces.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/stoneinterface.gif

Figure 4.1.14
Humans can upload images and audio to the system.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/citizenparticipation.gif

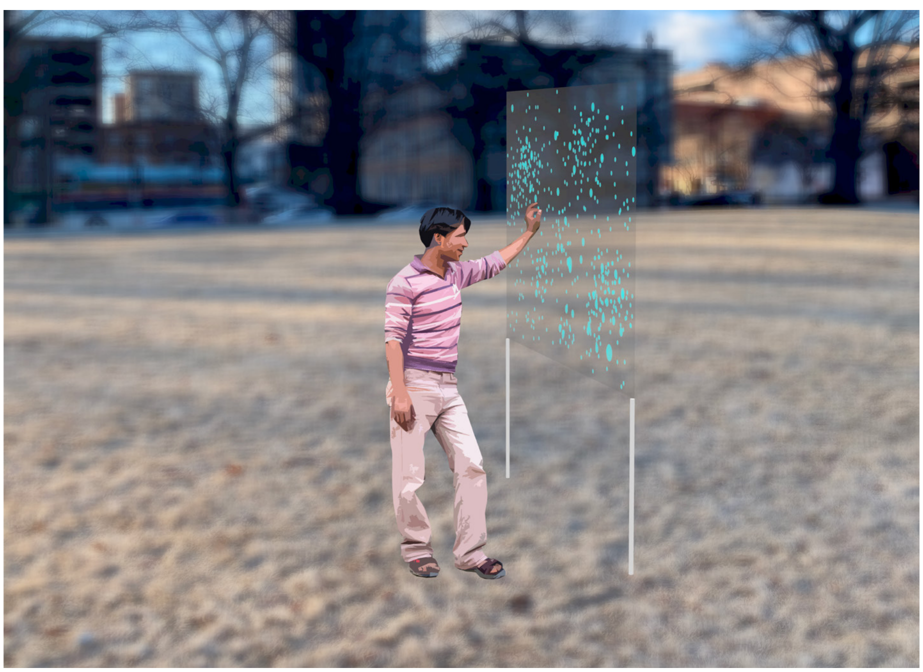


Figure 4.1.15
A shared, interactive bulletin board located in a public space.

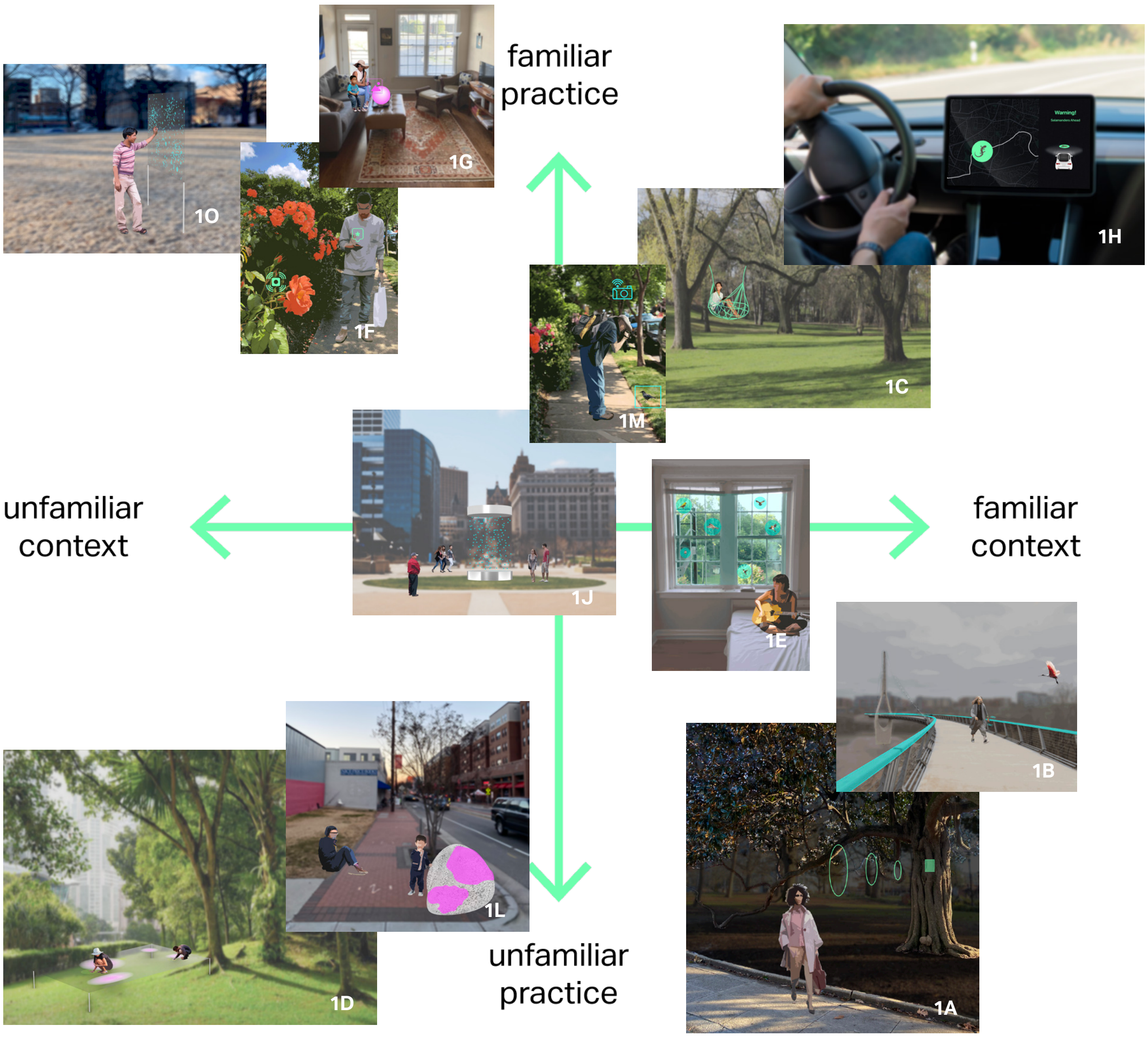


Figure 4.1.16
Explorations from study 1 mapped across the familiarity matrix.

4.2 Attunement: Experiencing the Data

How can a data presentation highlight patterns and aggregations of data to attune human participants to changes in the lifecycle of the nonhuman collaborator?

APPROACH

While study 1 establishes where potential interfaces may function in relation to the human environments, study 2 asks: once the human is at the site of the interface, how do they experience the data? In this study I carried forward the threads of interfaces from explorations in study 1 shown in figures 4.1.12, 4.1.11, and 4.1.3, and examined data associated with the lichens, birds, and trees at the respective interfaces. I chose to design around micro and macro thresholds of data to show the meaning of the data for the nonhuman. These thresholds articulated whether the ecological conditions altered the health or behavior of the nonhuman, and if so, how. I directed attention to these specific factors as a strategy toward attunement.

PROCESS

I developed a journey map, shown in figure 4.2.1, to identify when human users would meet the site of the interface, and what specific data might be relevant to them at that moment to consider forms of data and interactions that would feel significant or ceremonious. At the interface between the human and lichen (figures 4.2.2-4.2.9) and the interface between human and tree (figure 4.2.17) I chose to design around data that had implications for both the human and the nonhuman to draw in the human at more transitory moments in their day. In my iterations for the interface between human and lichen, allowing the human to experience otherwise invisible air quality data was particularly compelling. One possibility for showing the shared impact of the data on the human and the nonhuman was to visually represent the human. Figure 4.2.9 achieved this by reflecting the image of the user into the scene adjacent to the data presented in the form of a living creature. As the environment visually changed, both forms were impacted. In another iteration at the interface between the human and tree the shared impact was demonstrated through a multi-modal interaction. Figure 4.2.17 shows an audio interaction in which pitch corresponds with the level of pollen generated by the tree. While the tree is the producer of the pollen, humans are also impacted as they breathe the air. In this case the sound is not singularly representative of the tree nor the human's experience, but ambiently represents the environment that both beings coexist within.

Iterations of data experiences at the interface shown in figure 4.1.11, utilize the affordances of its integration into public space to create community-wide interactions. One representation, in figure 4.2.15, supports community participation through visual density. As humans upload their sightings of birds throughout the city, a 360 degree screen becomes increasingly populated with spheres representing the individual sightings. Through visual accumulation, citizens are able to recognize that their contributions are a smaller piece of the communal whole. They may see that community-wide participation in data sensing and gathering can create a fuller picture of the local ecology. In a second representation, shown in figure 4.2.13, a slow, real-time display of information creates a community-wide interaction that is anticipatory. The 360 screen depicts the multi-week migration of birds by showing them as abstracted circles moving closer by growing in size and shifting position each day. Centering the interaction around a long-term event encourages the human to return to the interface to monitor changes.

Experiences of ecological data should be as lively as the nonhuman experience they attempt to convey. While the interactions around the interface between human and bird represents data as lively by using a style of motion that mirrors the physical movement of birds, the other interfaces use dimensions that represent metrics that cannot be observed by the human. Figure 4.2.9 visualizes the internal livelihood of a still lichen by presenting multiple layers that react dynamically through motion and opacity to changes in the abstracted environment. In this iteration as well as in figure 4.2.8, layered dimensions of data present a complex schema of the nonhuman experience and allow the human to dig into individual components. At the interface that makes pollination audible, the livelihood of the tree is likewise represented using motion, but in sound, through movement in pitch. While a companion screen to aid users in interpreting the data, this interaction suggests that multimodal interactions with the data brings the human closer to the nonhuman as they embody the experience of the nonhuman rather than mediating it through a screen.

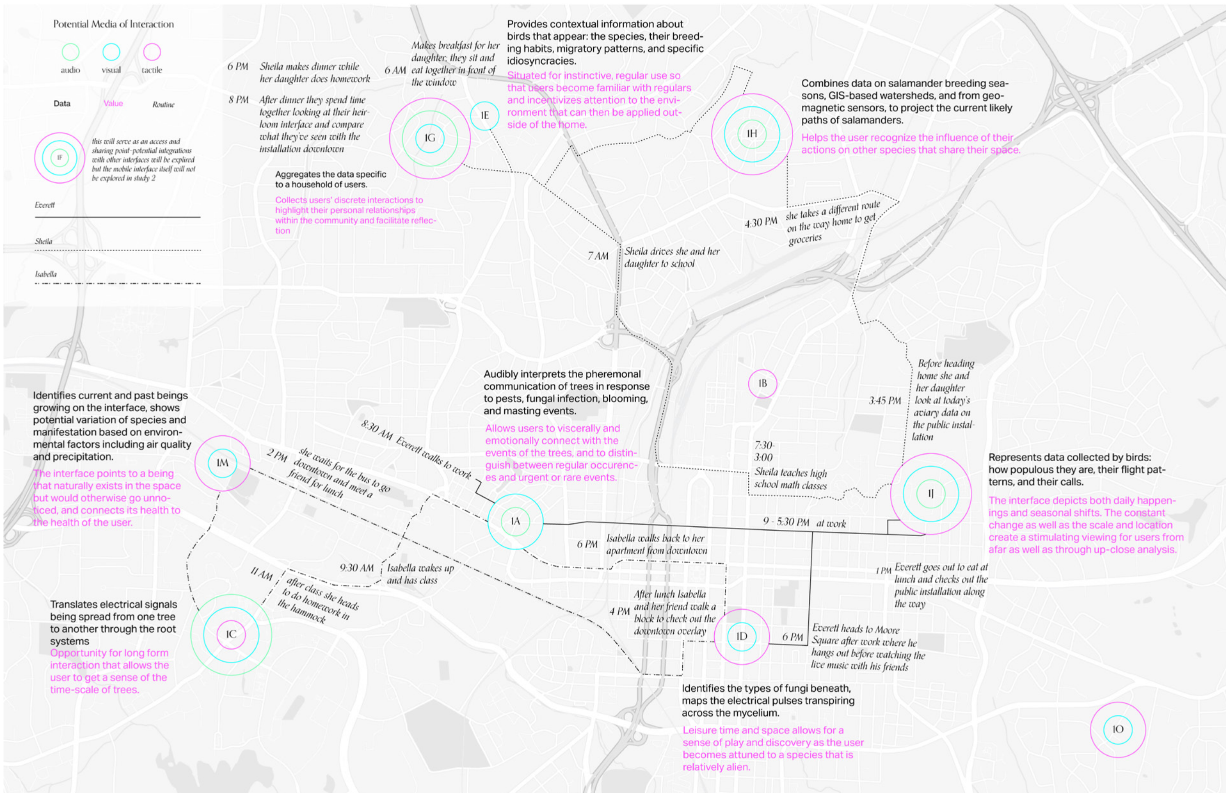


Figure 4.2.1
A journey map that details where users would interact with the interfaces during their day, the data they would experience, and its implication at that particular moment.

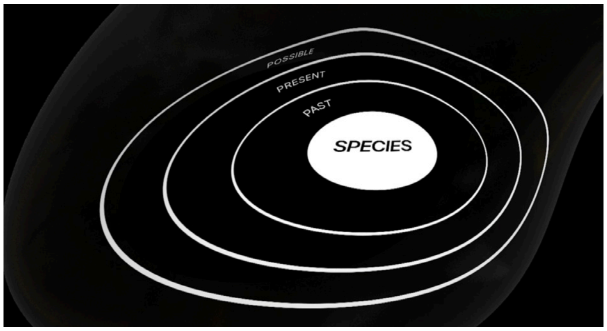


Figure 4.2.2
An intelligent stone surface with a menu that humans could select from to view data about past, present, and possible species at the site.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/surfaceinterfacemenu.mp4

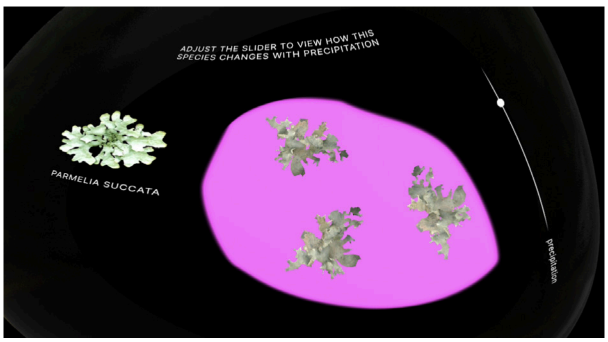


Figure 4.2.3
The human could identify lichen species presently growing at the site and visualize how their form might change with precipitation.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/surfaceinterfacepresent.mp4

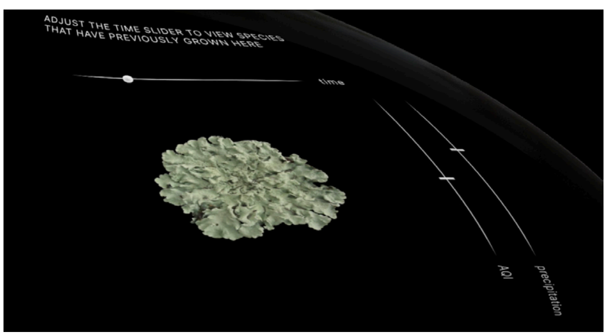


Figure 4.2.4
The human could scroll through time to see images of past lichens at the site and what the air quality and precipitation levels were at the time.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/surfaceinterfacepast.mp4

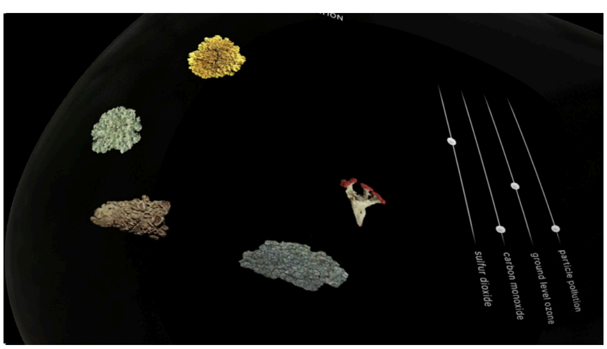


Figure 4.2.5
The human can adjust dimensions of the air quality index to see what lichens can possibly grow under the various conditions.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/surfaceinterfacefuture.mp4

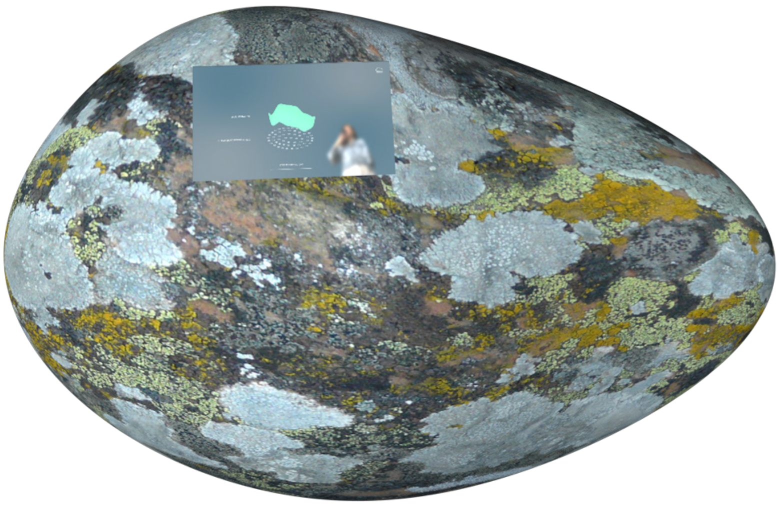


Figure 4.2.6
A screen interface attached to a stone with lichen growth that conveys the data captured at the site through sensors and relates it to the state of the species at the site.

Figure 4.2.7
The embedded interface shown in a possible environment.

Figure 4.2.8
A still of a data visualization that the human could interact with at the embedded stone interface. This data interaction allows the human to toggle through specific dimensions of lichen health in real time.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/geometriclivingdata.mp4

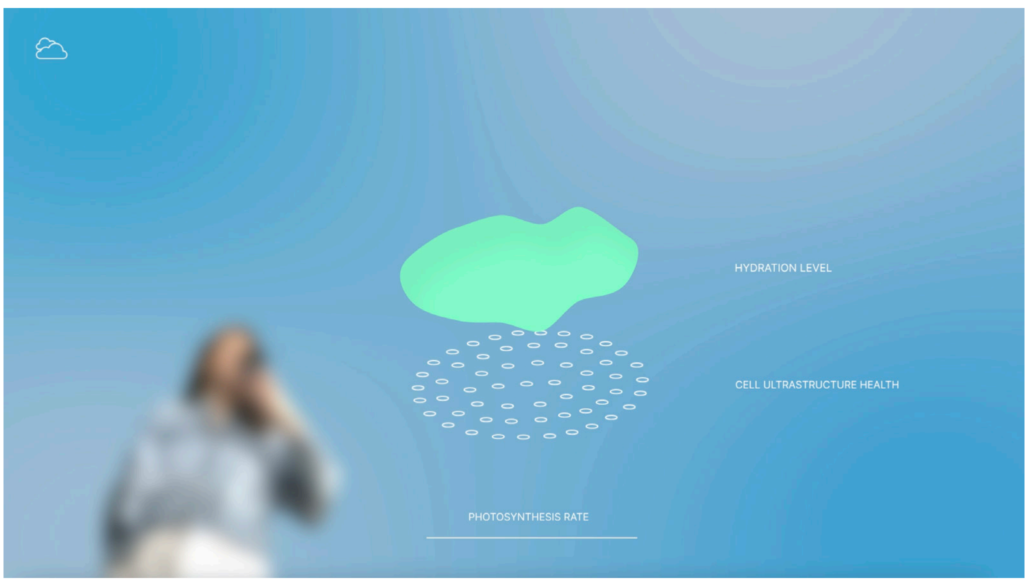


Figure 4.2.9
A still of a data visualization that the human could interact with at the embedded stone interface. This interaction conveys the data as a 'data creature' being impacted by environmental conditions in real time. The human is reflected into the interaction.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/datacreature.mp4

Figure 4.2.10
A 360 degree screen that displays data as a public installation. This visualization shows bird flight paths in real time.

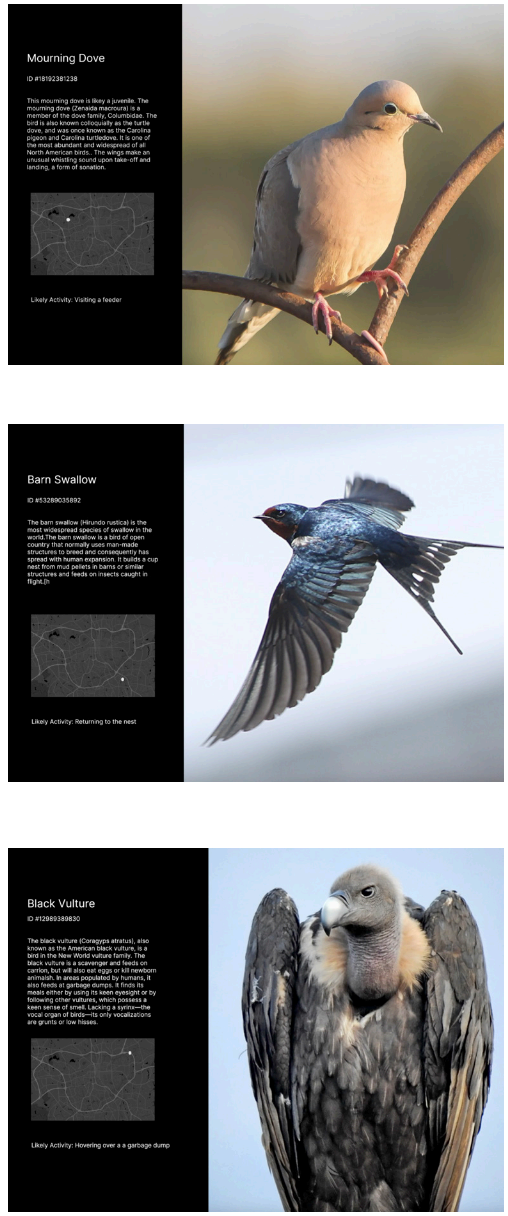


Figure 4.2.11
A visualization that uses RFID sensors to show bird flight paths in real time.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/flightpaths.mp4

Figure 4.2.12
Companion screens that would appear alongside the live flight paths.

Figure 4.2.13
A prolonged interaction that shows the approaching migratory birds over the course of several weeks.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/migration.mp4

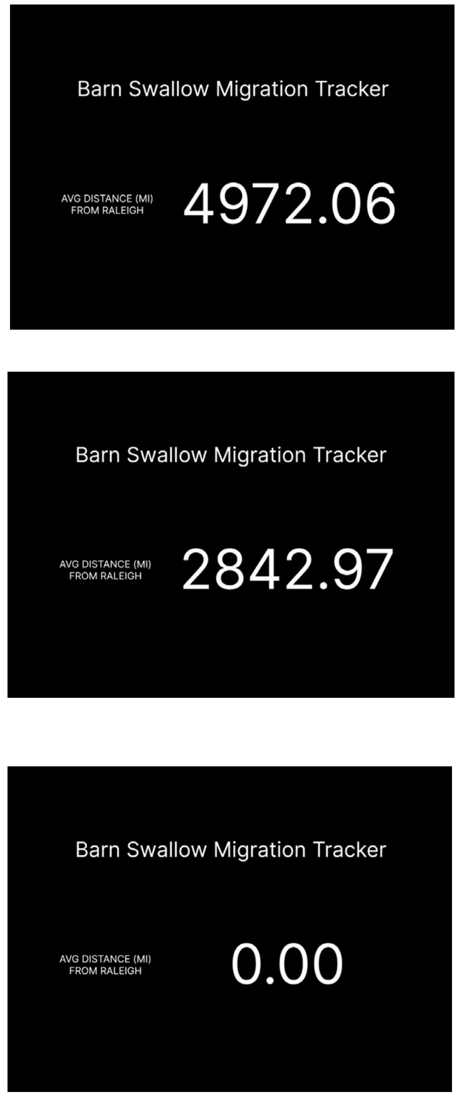


Figure 4.2.14
A companion screen that shows the average distance between the migrating birds and Raleigh. It acts as a countdown.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/migrationavgdistance.mp4

Figure 4.2.15
A community aggregation of bird sightings. As humans check in their bird sightings they would populate the 360 screen. Users could tap on a sighting to learn more about it.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/communalaggregation.mp4

Figure 4.2.16
A companion screem that shows what the user would see when they select a sighting on the 360 screen.

Figure 4.2.17
A real-time data interaction in which pollination levels at the site of the tree are mapped to pitch and made audible through sound. This sonification of data is accompanied by a companion screen that acts as a key for viewers.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/pollinationsonification.mp4

4.3 Expansion: Intertwining Relations

How can the interaction options change in relation to the experiences of others' interactions at different points in the system to foster a sense of community interdependence in human participants?

APPROACH

An ecology is a tangled web of relations. While environmental data might be gathered in one physical location, it likely impacts the rest of the ecosystem. This study focused on developing a relational system of resonance activities as interactions to make the interconnected nature of our more-than-human communities tangible. Contextualizing these interactions in a system that would be led by a community of citizen-scientists required applying practical constraints that included limiting sensors and developing a lightweight, affordable infrastructure.

PROCESS

Early in the development of this study I made a decision to distinguish the type of interaction at the interface between bird and human based on the data being conveyed. While the interfaces located near the lichen and tree represent data gathered in close proximity, the interface for birds creates a centralized access point for bird activity data gathered across the city. Here, the interaction is twofold: lights synchronize with the various birdsongs in the neighborhood, and when the human enters into close proximity to the interface their companion screen shows those birdsongs in the context of a map and plays the associated audio (figure 4.3.13). Unlike the other interfaces, the first layer of this interaction is visual because the human is not being drawn closer to the nonhuman in context, but monitoring distributed activity. Ambiently displaying the bird activity at the heart of the city positions the nonhuman as an important part of the community. Lights successfully highlight incongruencies that appear in the data at night. On the data overlay where birdsongs are contextualized by a map, names of neighborhoods integrated into the map allow a wide population of users to draw personal connections (figure 4.3.7). Seeing the nonhuman as a resident of their own neighborhood aids in blurring the nature-culture division.

In each of the in-situ interactions at the interfaces near the lichen and tree the companion data screens visually represent the impact of the sensor-gathered data on the nonhuman's internal state. Here, I applied visual 'traces' as a strategy for showing long-term versus short-term impact. As shown in figure 4.3.1 a gradient map visually activates parts of a tree that the data suggests are holding water. These highlights create a new form that emphasizes the concentration of energy within the nonhuman. By allowing humans to scroll back through time, as demonstrated in figure 4.3.2, the user is able to see which data traces fade and which remain. This distinguishes long-term impact from short-term impact. Multimodality is a key feature for distinguishing the quality of the nonhuman's experience. In the case of the interaction with the lichen demonstrated in scenario (figures 4.3.4-4.3.6), the audio distinguishes higher air quality, a dimension that negatively impacts the lichen, with a sharper sound, while increased soil moisture, a dimension that relates to the lichen's hydration, is accompanied by a more resolved sound. Associating the quality of the data's impact with the experiential component of an interaction allows humans to directly take on the perspective of the nonhuman, thereby heightening empathy.

Each time the user receives a beacon notification and views a companion data screen, the screen shows the state from their last interaction at the interface before transitioning to the current moment (figure 4.3.2). Rather than solely showing real-time data, this form of interaction makes the human's encounter with the nonhuman personal. The human witnesses the nonhuman change in direct parallel with their relationship. Sequestering intentional moments between the human and nonhuman speaks to the earlier referenced archive feature. The iterations shown in figures 4.3.19 and 4.3.20 suggest two different ways such an archive might be used: for community sharing and advocating. The search associated with social sharing shows high level qualitative data such as image and audio that allows users to swap and reminisce on various experiences, the search associated with communities advocated requires highly specific, narrow, quantifiable data such as the exact air quality level over a period of time as shown in figure 4.3.20.

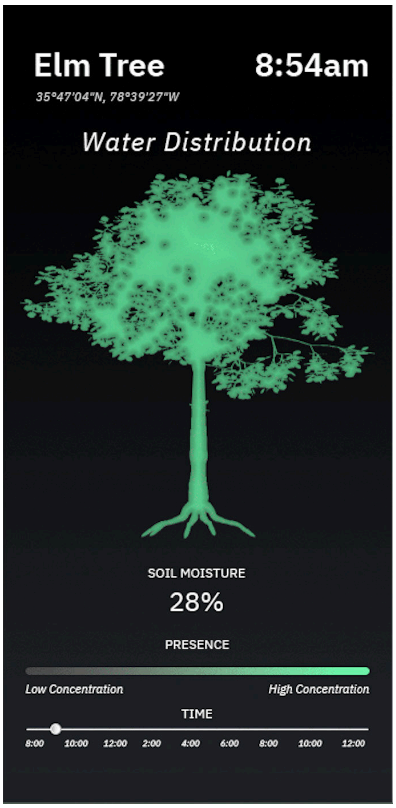


Figure 4.3.1
Companion screen to a haptic interaction that shows water distribution throughout a tree during the day.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/treeinterfacewater-dispersion.gif

Figure 4.3.2
Companion screen to a haptic interaction that shows water concentrated in the trunk of a tree in the evening.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/treeinterfacewater-concentration.gif

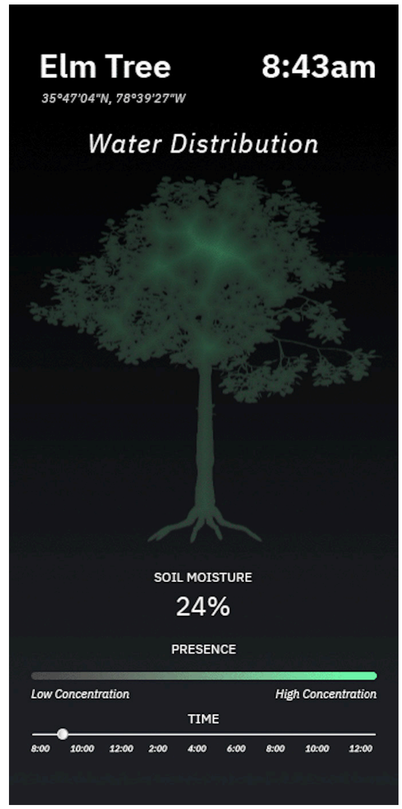


Figure 4.3.3
A companion screen to a haptic interaction that shows the influence of construction on a tree's water intake.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/treeinterfaceconstruction.gif

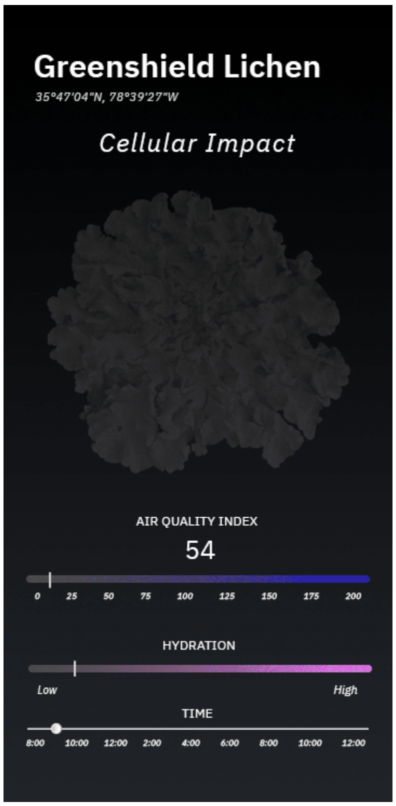


Figure 4.3.4
Companion screen to an audio interaction that shows the impact of air quality on the lichen.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/licheninitialairquality.gif

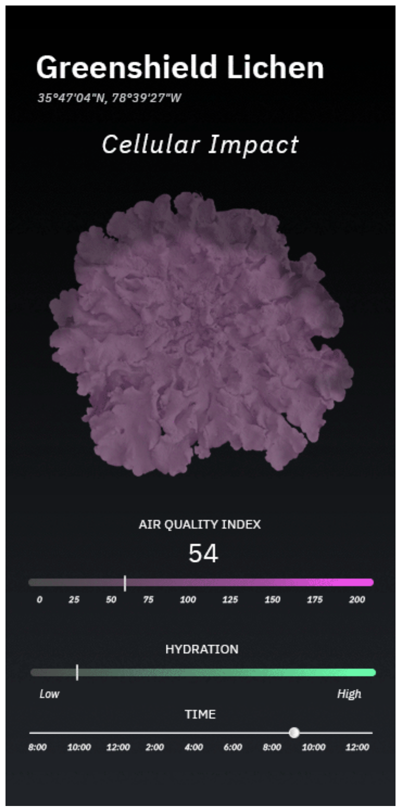


Figure 4.3.5
Companion screen to an audio interaction that shows the impact of soil moisture on the lichen.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/lichenhydration.gif

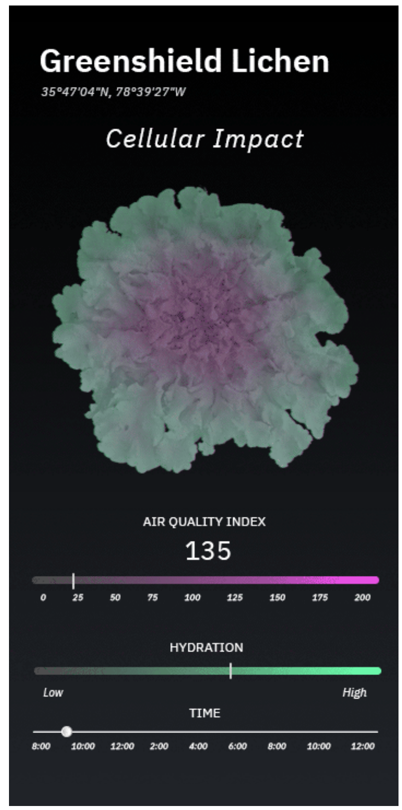


Figure 4.3.6
Companion screen to an audio interaction that shows the impact of construction on the lichen.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/licheninstruction.gif

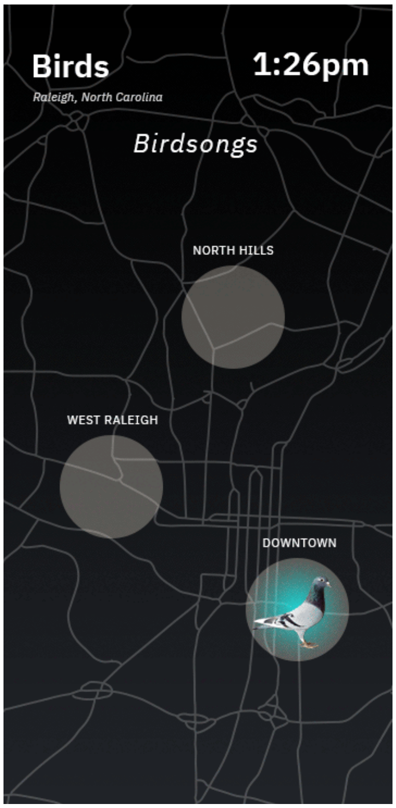


Figure 4.3.7
Companion screen to an audiovisual interaction that shows live birdsongs throughout Raleigh neighborhoods.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/birdnormalday.gif

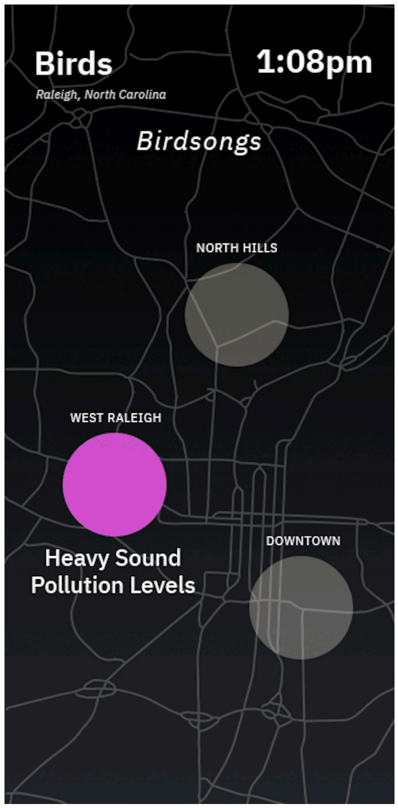


Figure 4.3.8
Companion screen to an audiovisual interaction that shows live birdsongs throughout Raleigh neighborhoods during a construction event.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/birddaytimeconstruction.gif

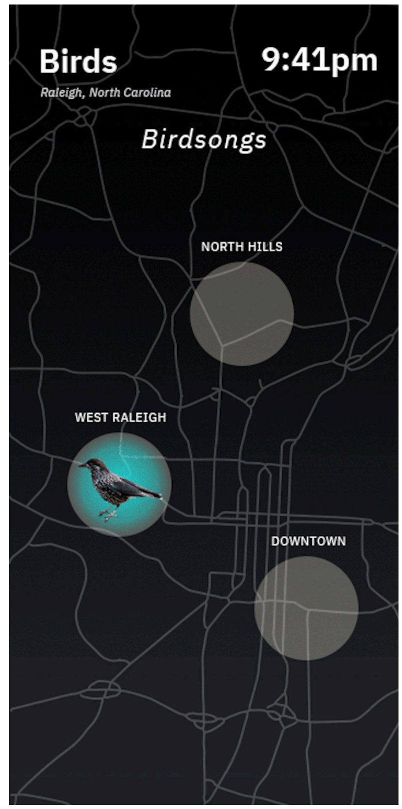


Figure 4.3.9
Companion screen to an audiovisual interaction that shows live birdsongs throughout Raleigh neighborhoods in the evening during a daily construction event.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/birdnighttimeconstruction.gif

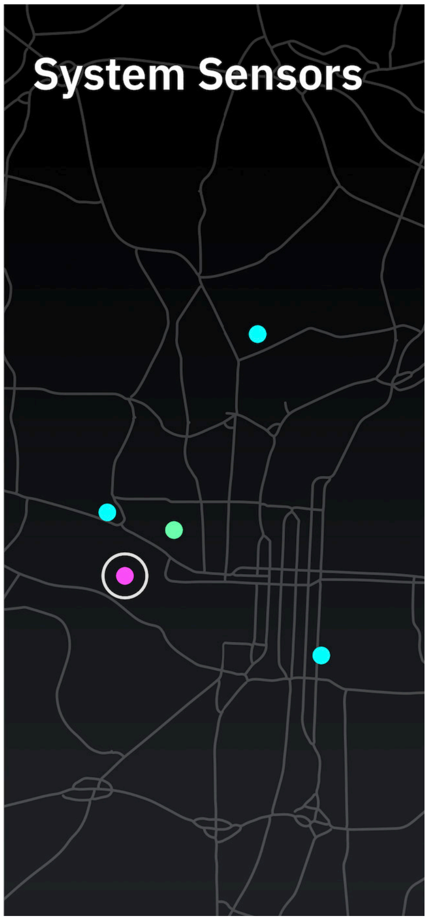


Figure 4.3.10
A companion screen that shows where a user is in relation to the system

VIEW ANIMATION:

https://college.
design.ncsu.edu/
thenfinally/feldman/
userlocation.gif

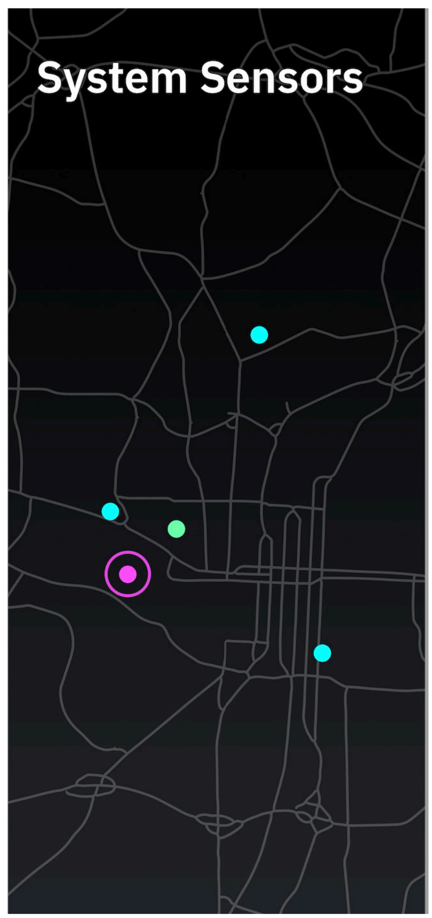


Figure 4.3.11
A companion screen that shows data influence from multiple locations in the system

VIEW ANIMATION:

https://college.
design.ncsu.edu/
thenfinally/feldman/
sensorinfluence.gif

Scenario

The following text and videos detail multiple interactions that users Isabella and Everett experience with the system over time.

Figure 4.3.12
A screengrab of lichen interaction 1.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/licheninterfacescene1.mp4

LICHEN INTERACTION 1
Isabella is a perpetually curious college student studying in Raleigh, North Carolina. While searching online recently for information about local insects, she found the website for Raleigh's community eco-sensing group, and signed up for alerts from their city-wide system.

Isabella takes the local transit system to class early in the morning. While waiting at her stop, she gets her first notification from the system. A beacon from one of the system interfaces alerts her that she is near the interface for lichens. The beacon simultaneously activates a speaker and Isabella notices the sound is corresponding to the real-time air quality measurement.

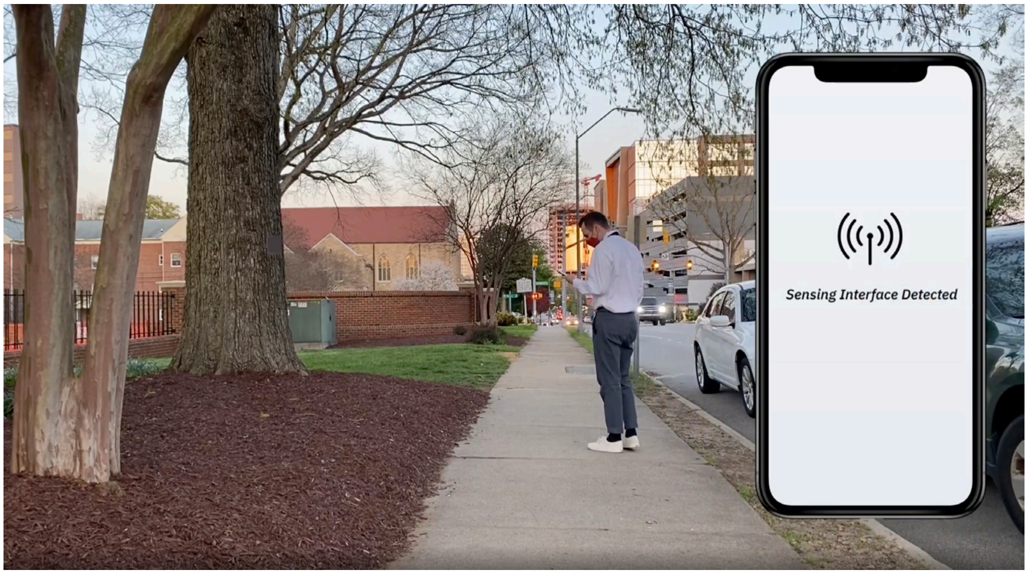


Figure 4.3.13
A screengrab of tree interaction 1.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/treeinterfacescene1.mp4

TREE INTERACTION 1
Everett is a young professional living and working in Raleigh. He wants to spend his time outside of work in meaningful ways, and recently learned about the local community eco-sensing group. Everett typically walks to work, and on the way he pauses at one of the system interfaces.

A beacon notification alerts Everett that he is at the interface for trees. He rests his hand on the haptic interface and feels a series of light, brief, pulses that he sees correlates with the movement of water throughout the tree generated in relation to the soil moisture levels and time of day.

BIRD INTERACTION 1
Later, on his lunch break Everett gets takeout from a nearby restaurant and encounters the interface for birds. Here he sees the lights on the physical installation light up periodically, and when the beacon sends a notification to his phone he opens it to find that the physical lights relate to the current bird songs being sung in different neighborhoods. He listens to the birds in different places and taps to learn what species are near his home.

Figure 4.3.13
A screengrab of bird interaction 1.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/birdinterfacescene1.mp4

BIRD INTERACTION 1

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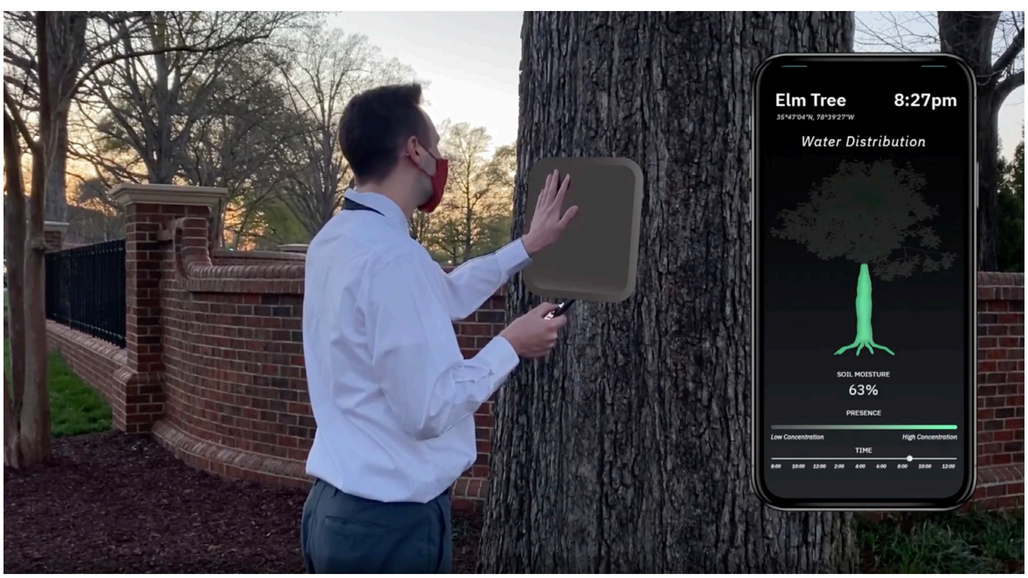

Figure 4.3.13
A screengrab of bird interaction 1.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/treeinterfacescene2.mp4

TREE INTERACTION 2

Because it rained in the afternoon, Everett stayed at the office a bit later. In the evening he walks home and passes the tree interface again, but when he touches it this time he feels heavier, sustained pulses. He sees that the water levels are higher, and mostly concentrated in the trunk. He scrolls back through time and recognizes that the rain and change in water dispersion are unrelated events.

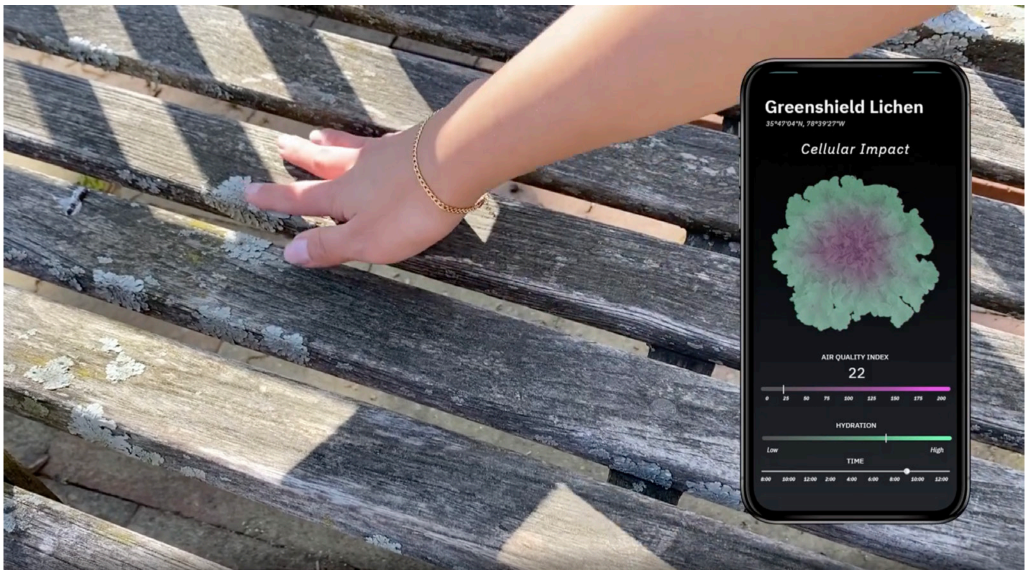

Figure 4.3.14
A screengrab of lichen interaction 2.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/licheninterfacescene2.mp4

LICHEN INTERACTION 2

The next morning at her stop, Isabella receives a notification from the system and sees that the data gathered at the interface for trees is influencing activity at the interface for lichens. Even though the air quality level is lower today, she notices that the traces do not fade. She sees the influence of the soil moisture data and hears a corresponding sound.

Figure 4.3.16
A screengrab of lichen interaction 3.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/licheninterfacescene3.mp4

LICHEN INTERACTION 3

Later in the week on the way to the bus stop, Isabella notices construction has begun on nearby apartments. At the bus stop she checks the interface for lichens. As it calibrates a sharp sound comes out of the speaker and she sees the air quality level is very high. She recognizes that the construction is heavily influencing the air quality that both she and the lichen experience.

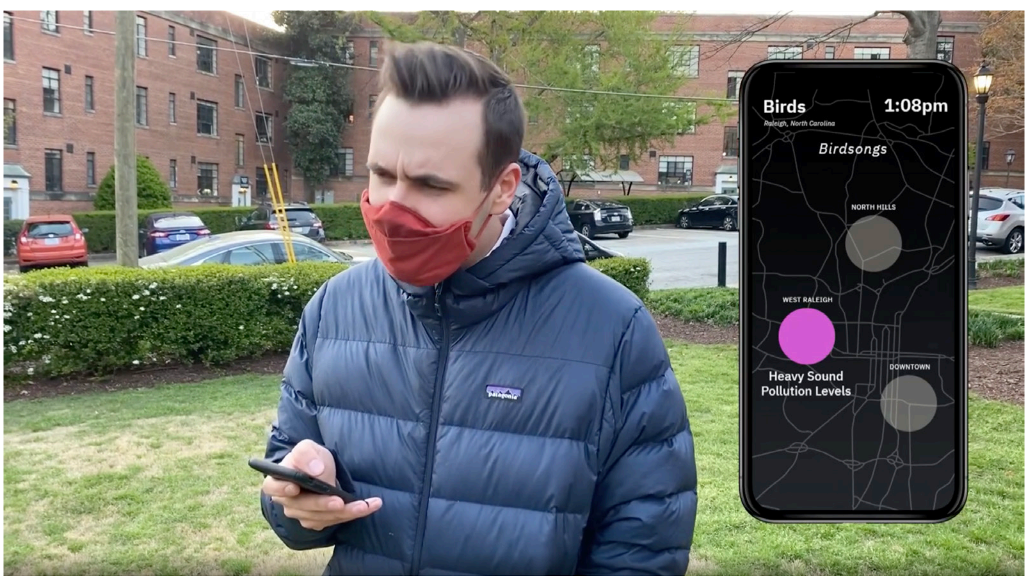

Figure 4.3.17
A screengrab of bird interaction 2.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/birdinterfacescene2.mp4

BIRD INTERACTION 2

While Everett is out to lunch he notices that the lights on the installation are not flickering as much as yesterday. He moves closer to the installation to trigger a beacon. On his phone he sees that data from the interface for lichens is influencing activity at the interface for birds. He notices that there are no birds singing near the sensor located in the neighborhood adjacent to the interface for lichens.

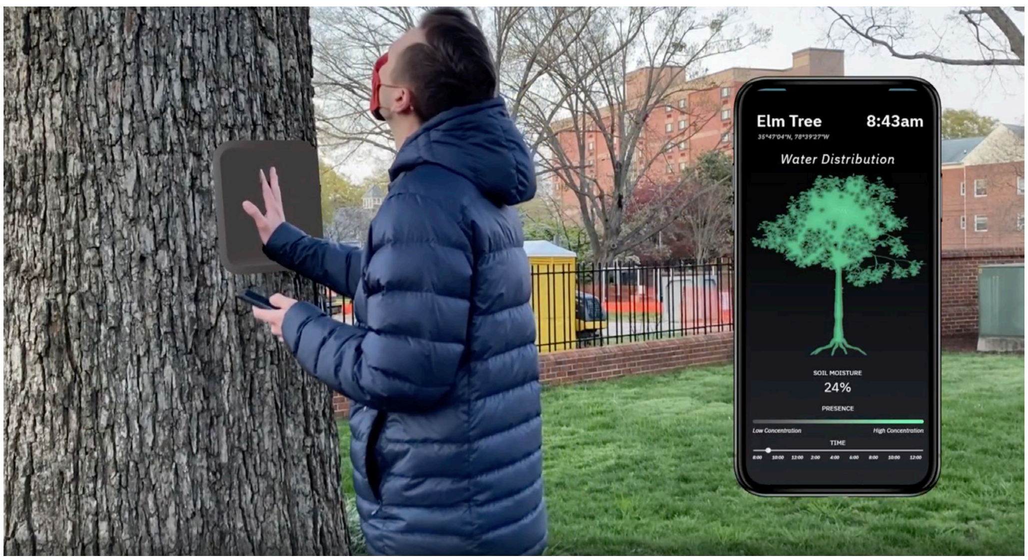

Figure 4.3.18
A screengrab of tree interaction 3.

VIEW ANIMATION:
https://college.design.ncsu.edu/thenfinally/feldman/treeinterfacescene3.mp4

TREE INTERACTION 3

On his walk home from work Everett sees the construction near the interface for trees. He gets a notification that the same noise and sound event that affected the birds is influencing activity at this interface as well. He sees that despite adequate levels of soil moisture, the system suggests that the tree is unable to distribute water. He sees the tread marks where machinery has driven over the soil and gathers that the construction is likely impacting the tree's roots.

Figure 4.3.18
A screengrab of bird interaction 3.

VIEW ANIMATION:

https://college.design.ncsu.edu/thenfinally/feldman/birdinterfacescene3.mp4

BIRD INTERACTION 3

To celebrate the weekend, Everett has drinks with friends. As he leaves the bar, he notices a lot of light coming from the installation in the park. He approaches the installation and sees that the birds in the neighborhood with construction are now highly active in the evening. He thinks back to his interaction at the tree and reflects on the ripple effect the construction is having throughout the ecosystem.

Figure 4.3.19
A community achive screen that shows various user check-ins in response to the question "what birdsongs have my friends heard?"

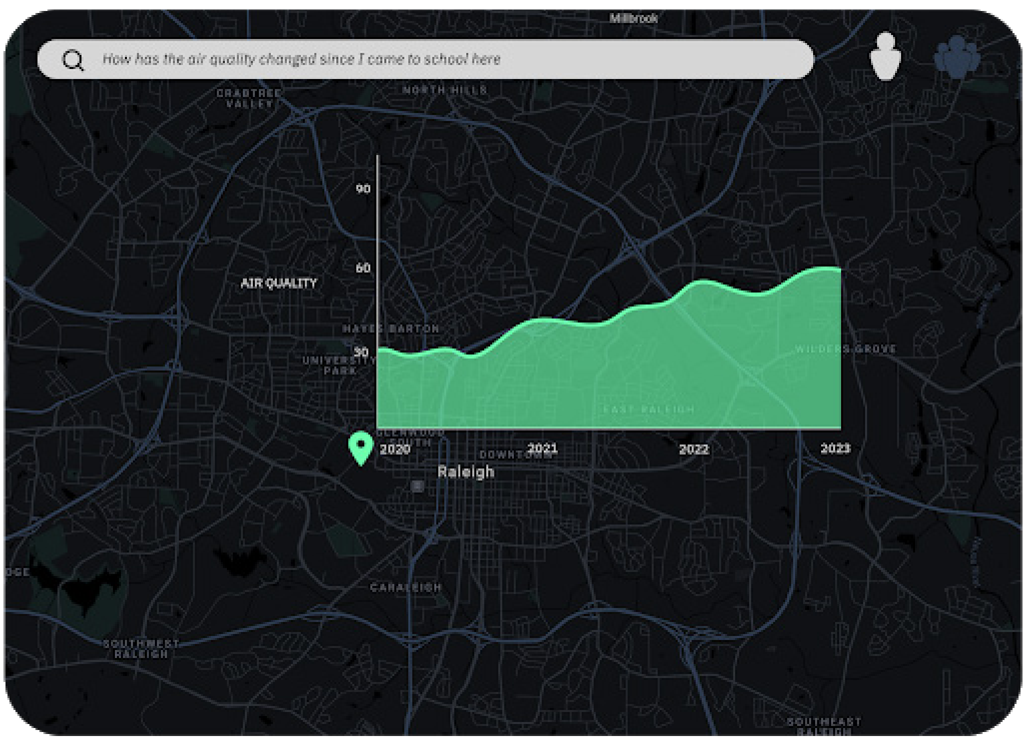

Figure 4.3.20
A community archive screen that shows the measurement of air quality across all of Isabella's interactions at the interface between she and the lichen since she has been in school.

Discussion

5.1 Design Principles

Throughout this design process, several findings emerged that may be fruitful sources for future designers and researchers.

Meet the Human Where They Are
Nature is not 'out there.' Nature is integrated into our environments in ways that are often unrecognized in our daily interactions. These "everyday spaces" present opportunities for expanding our perspectives through experiential design interventions that challenge habitus. By becoming a space for alternative interactions, the space changes in meaning. The context should remain familiar, and the practice should become strange. (Study 1)

Long-form Interactions Help the Human Perceive Scale
A single, prolonged interaction with data allows users to perceive the time-scale of a nonhuman. These interactions allow the human to experience an activity at the same rate as the nonhuman lives it. Sharing the nonhumans' experience creates a level of intimacy that deepens their relationship. As the human experiences these interactions in the context of their own daily life and space, they become aware of, and temporarily step into, the parallel worlds moving at different speeds around them. (Studies & 2)

Decouple the Data
Data is more fully understood when it takes multiple forms and is presented in multiple contexts. Study 3 demonstrates

how different forms have unique affordances: the multimodal data interaction enables the user to viscerally experience the perspective of the nonhuman while the companion screen allows them to dig into the data from a more quantitative perspective. Additionally the data becomes more robust if the user sees its impact in multiple contexts. Environmental data is not linked to a single species. When the data is visually associated with multiple nonhumans the human can begin to mentally articulate relationships within the local ecology. (Study 3)

Community-Wide Interactions Can Instill Pride

Throughout this study, interactions that involved the entire human community, whether ambiently or actively, created a sense of participatory kinship. Studies 1, 2, and 3 demonstrated that data as a public installation in the urban environment creates a sense of pride. The large scale and central location subliminally associates the interface with statues and monuments that possess the same quality, and in some cases, represent their community. Similar emotional associations are activated by the data installation, and it becomes a living monument representative of a larger, more inclusive community. When the data is populated by the humans themselves, such as in the archive iterations of study 1 and 3, and the community repository of study 2, they become accountable for the representation of their community. Through visual density they are able to see their community grow as a whole in relation to collective data gathering practices, and are individually incentivized to participate and add to it. (Study 1, 2, & 3)

Individualized Data

An interaction with data that changes according to user presence, as illustrated in study 3, is more personal than a universal livestream of the data. By only updating when the user is present the data feels less like an objective, impersonal source of information, and more like a relationship slowly developing with time and care. With this dynamic the interaction becomes a sort of ‘check-in’ which encourages regular, intentional interaction on behalf of the human. (Study 3)

Multimodal Staging

Multimodal interactions allow humans to perceive shared connectedness to a place or group. In study 2, the sonification of pollination is a data interaction that both human and tree take part. A multimodal interaction can also be staged to impact the human's perception of their community's territorial and sociocultural distinctiveness. In study 3, the audible birdsongs exemplify this potential. As the human hears and is able to associate the unique bird songs with physical locations, their own neighborhood becomes distinctive through the birds that inhabit it. Multimodal interactions that address these dimensions can directly alter humans' mental models of community (Puddifoot, 1995). (Studies 2 & 3)

5.2 Future Work

While these findings hold true within the context of this investigation, there is further work to verify, build upon, and apply their meaning. These findings indicate potential opportunities for further research on multi-species interactions and systems. Additionally, specific findings may be applied to spaces outside of this particular field.

Expanding the Community Archive

The majority of this investigation focused on how the human experiences and personally collects data. The studies indicate a need and desire for a means of archiving and accessing materials after the interaction. While I present representations of potential formats and uses of an archive in several studies, it would be pertinent to explore methods of sorting, packaging, sharing, and personalizing the data at greater depth. Individual interactions bring the human closer to the nonhuman, but further inquiry toward archive forms and functions could allow communities to advocate for these relations based on scientific data.

Advanced Prototyping & User-Testing

Multimodality is crucial to the interactions designed in this investigation. Allowing real users to experience them may provide additional insight toward the effectiveness of haptic and audio forms. It is possible the interactions might change as they are developed based on practical constraints or material possibilities.

Facilitating Interactions for the Nonhuman

Ideally this system would allow nonhumans to gather and interact with data in the same capacity as humans. Partnerships with experts on the participant species would aid in identifying possible modes for safely and respectfully delivering useful data to the nonhuman, as well as enabling them to gather and generate additional data through their daily practices.

Civic-Integration

As a robust, developed, system, an additional area for further research encompasses what it would look like as a civic integration. While the scope of this investigation focuses on expanding our internal conception of community, civic integration externalizes this inquiry. Including nonhuman data in local our governing systems raises questions and opportunities toward changing the way we organize to live and build our lives together. Validating and prioritizing the needs and values of a multi-species community is a critical pathway toward sustainable futures of multi-species flourishing.

Understanding Other Intelligences

Artificial intelligence is becoming increasingly sophisticated and simultaneously opaque. Design that brings us closer to understanding the radically diverse and complex intelligences of other species could help us create more accurate metaphors for artificial intelligence. Additionally, methods generated by this inquiry could be broadened and applied to present artificial intelligence in action.

5.3 Conclusion

I structured this investigation toward new modes for developing kinship between the human and the nonhuman. The studies explored possible sites of mediation for engagement of the human with the nonhuman, how the experience of the data at the site could attune the human to the perspective of the nonhuman, and processes of interactions that help the human articulate interdependence. The results of the studies are not fixed answers or solutions, but possibilities that can be reapplied or further developed toward new modes of eco-social relations.

Present systems of power, production, and consumption do not serve multi-species flourishing. Design that builds a relationship between the human and nonhuman that is both personal and communal creates space for alternative value systems. Interactions that allow the human to perceive the scale of the nonhuman have implications toward not only a deeper understanding of the nonhuman themself, but of how processes and acts of ecological degradation impact their experience. The findings of this study present pathways toward alternative worldviews that acknowledge the complexity of ecology, recognize the imperative of collaborative survival, and embrace new ways of respecting, honoring, and co-existing with the nonhuman.

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Appendix

Appendix A

A list of sensors and other technologies that would be employed in the explorations of this invesitgation:

- Proximity sensor
- Sound sensor
- Rain sensor
- Soil moisture sensor
- Temperature sensor
- Humidity sensor
- RFID sensor
- Light sensor
- Smartphone detector sensor
- Air quality sensor
- Motion sensor
- Electrical current sensor
- Image recognition
- Sound recognition

A note on typography.

This document is typeset in Friezeit and Aktiv Grostesk. Designed by Lewis Macdonald, Freizeit is a Neo grotesque drawing inspiration from the mid-century triumvirate of Universe, Neue Haas Grotesk and Folio, as well as some of the sans that preceded them. Aktiv Grotesk was designed by Dalton Maag.