Tsuga Convictio: Visualizing for the ecological, feminine, and embodied

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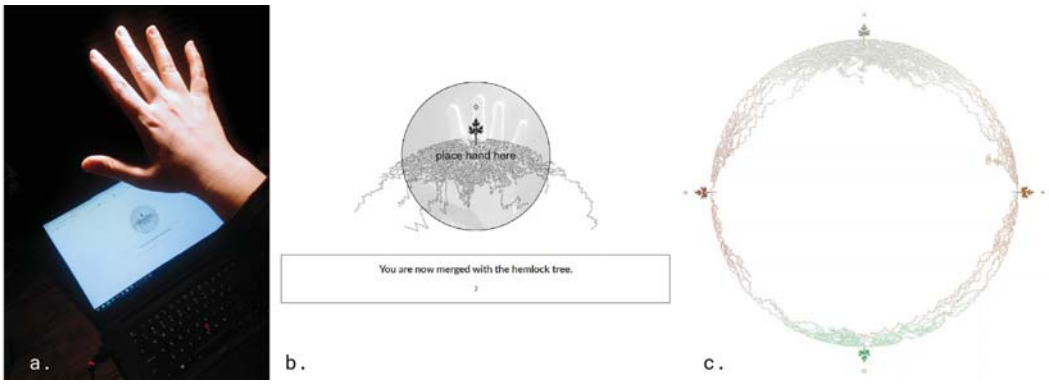

Fig. 1. a. Using an opening and closing hand gesture to collect felt experience as data b. Data collection interface, in which gesture is metaphorically represented by tree roots c. Data visualization of multiple gestures, metaphorically displayed as a forest of hemlock trees

Abstract—A good data visualization opens up space for good conversations. That is, a data visualization is a starting point in a discussion of a shared understanding of the world, a way for us to know together. Consequently, our practices as data visualization designers—through collecting data and portraying them visually—create (or reinforce) ways we can understand the world, and thus move through it—it's ontological. Alarmingly, there is an emerging sense among new media artists and scholars that our practices of collecting and visualizing data can create rigid, harmful understandings of the world; ontologies of control. In particular, D'Ignazio and Klein argue in their book, *Data Feminism*, that our current practices of data science can lead to the "silencing, extraction, monetization, or invisibility" of people (or other living things) that the data represent [9]. In response to this violence, they assert that we need to make visible those who are creating the data, and those who are represented by the data. In other words, we need to "bring back the bodies." This research interrogates how we might recenter the embodied, situated nature of data through the design of Tsuga Convictio, an experimental data collection process and a data visualization to support the conversations critical to our future—the reflective community conversations that help us belong to our human and ecological communities. By designing for these conversations, we discovered fluid, feminine, and embodied ways to create—and (re)enchant data visualizations. Along the way, we begin to answer some of the fundamental questions designers implicitly (and explicitly) answer when they make data visualizations. Most profoundly, we (re)imagine what visualizations can do—data visualizations are more than just tools of control; they are tools for imagination and transformation.

Index Terms—data visualization, ecology, forests, storytelling, feminism, plurality, ontology, community, conversation, data dramatization, art

1 Introduction

As a medium, data visualizations are uniquely suited for supporting conversations, through revealing patterns and guiding how we engage with data. With the potential to allow us to behold and appreciate the unseen bonds that connect us, visualizations have the potential to support and enhance conversations that may transform our lives for the better. However, data visualization practices fall short of providing the theories and practices to deliver data-driven conversations beyond a mode of analysis and control. A critical challenge in the field is devising new ways to theorize and create data visualizations that allow us behold, inspire curiosity, and connect through the conversations they support.

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To address this challenge, we first identify two key ways of characterizing data and visualizations that may allow the retooling of data visualization towards one of enchantment, as opposed to control (section 2.2). First, we define data as always situated in bodies; that is, a data in an observation that always implies an observer. Second, visualizations are ontological; they foster ways of understanding, and thus relating to, the world around us.

Using the two ways of characterizing data and visualizations described above, we designed Tsuga Convictio, an experiment in data collection and data visualization to support community conversations (section 3). Critically, designing these experiments reveals methods and additional theories that data visualization designers can use to create visualizations that enchant and inspire. Finally, we distill those revealed practices and theories encountered in our design process into new answers of the fundamental questions designers implicitly (and explicitly) address when they collect data and create data visualizations (section 4). We frame our work as a research through design project, in which the act of design serves the goal of revealing alternative possibilities and practices for visualizing data (instead of being well realized as a standalone project in itself). A prototype of the data visualization can

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be found at cathrynploehn.com/tsugaConvictio/.

2 Background and context

2.1 Community conversations are the site of belonging and transformation

Belonging is a fundamental human need. Yet, we may feel "a radical brokenness in existence," [29]. To address this sense of fragmentation, we can notice how we are interconnected with the people in our lives through reflection and solidarity. In other words, when we behold each other, we become beholden to one another, as Odell writes [26].

Reflection and solidarity in our communities has the potential to be explosively transformational. In fact, this act of noticing our patterns of thought and behavior together is mandatory if we want our communities, and societies, to transform into life-affirming ones [11].

How do we tap into this powerful kind of community noticing? The answer is simple: conversation. In Turning to One Another, Margaret Wheatley identifies human conversation as the "most ancient and easiest way to cultivate the conditions for change—personal change, community and organizational change, planetary change (Wheatley, 2009). Conversation is simple, yet profound because of the feeling it gives us.

Through developing a ritual of conversation, communities become life-affirming places in which we can feel a sense of belonging. Even more deeply, conversations that embrace the "language of connection and relatedness and belonging" help us feel at home with one another [2]. Indeed, if we can regularly practice rituals, such as conversations, that allow us to notice our patterns of thought and appreciate our interconnectedness, we set the stage for finding belonging (see figure 2 for more detail).

2.1.1 We need artists and designers to help us sustain the delicate act of noticing

Worryingly, the crucial act of noticing how we are connected (in communities and beyond) is delicate. In *How to Do Nothing*, Odell argues that noticing "means foregoing all of the many easier and more habitual ways to "see," and as such, it is a fragile state requiring the discipline to continue" [26].

Art provides lessons on how to build tools sustaining this fragile state of noticing. Specifically, artists offer us "a kind of attentional prosthesis," in which they create the conditions for us to experience and notice our surroundings in a specific way [26]. We can draw from artistic practices in order to build attentional prosthetics that help us understand the world through different lenses and position us to feel our interconnectedness.

One key aspect of attentional prosthetics is the feeling of connection they give us [21]. In "Soma Literate Design," Neely calls this experience a form of embodiment, one in which we "feel-with" an artifact (art in this case) [22]. Another key aspect of attentional prosthetics is their ability to enhance and guide reflection. They give us rails to create and notice patterns in specific ways, easing the process of self expression, and thus reflection.

2.1.2 Data visualizations can be an attentional prosthetic for noticing

With its strengths for revealing patterns and guiding conversations about the world, data visualizations are a promising way to build attentional prosthetics that foster belonging.

Making patterns visible Alberto Cairo, prominent data visualization scholar, argues that data visualizations create good conversations by showing what we know visually [5]. Data visualizations display what we know, which can sometimes be intangible, into visible and discussable patterns. For designers like Giogia Lupi, designing with data means "designing ways to transform the abstract and the uncountable into something that can be seen, felt, and directly reconnected to our lives and to our behaviors…" [20]. In other words, data visualization designers are our attentional guides, choosing which patterns in our world we should notice and how. When designers show specific patterns, or use specific ways of visualizing data, certain kinds of conversations become possible.

Connecting to the world through feeling data Further, artists and designers already use data to craft attentional prosthetics, such as data dramatizations, to give us a feeling for the data. Data dramatization, through abstracting behaviors and creating simulations, is about "imbuing a data set with emotional attachment" [32]. Artists like Refik Anadol create "data sculptures" that pull us in, allowing us to get a feeling for the world through data with poetic displays [1]. Thus, data visualizations both focus our attention to particular patterns in the world, and, with poetic displays, can allow us to get a feel for those patterns. With these strengths, visualizations could be created as much needed prosthetics that help us appreciate our interconnectedness.

2.1.3 Violence in our data collection and visualization practices

As a medium, data visualization has the potential to transform us through guiding our attention. However, our data visualization theories and practices may fall short. In the context of community conversations—in which feeling, perspective, and nuance are key—the extractive qualities in typical practices of collecting and visualizing data come into sharp relief and result in an analytical (and disenchanted) conversation.

First, data collection tends to be an extractive, cognitive activity (see figure 3). In the context of a community conversation, a survey might be given out before discussion, asking participants to rank how they are feeling and who they feel connected to. Filling out a survey lends itself to logical thinking, not necessarily tapping into the feelings of the body - the tightness of the chest, etc. Even further, respondents may find themselves trying to ascertain the one true interpretation of the proctor's survey. In a typical survey, the unique, felt experience of the body is ignored, and multiple interpretations of the survey are discouraged in exchange for consistency.

Second, reading a data visualization tends to be an analytical activity (see figure 3). The focus on analysis comes from the typical characteristics of data visualization itself: for example, geometric shapes abstract away the people (and their stressed bodies) they represent. Even further, the people in the community are very much isolated in geometric visuals despite being very much entangled in the social texture of the community at large. Finally, the "truthy" aesthetic of geometric data visualizations may dissuade members from questioning whether there are any alternative views of the same community.

This pattern-oriented focus of data visualization design makes an understanding the perceptual properties of geometric shapes (lines, color etc.) essential and prioritizes the leveraging of principles of Gestalt psychology [18]. Kennedy et al. underline the strengths of abstract, geometric shapes in conveying patterns, yet note their association with objectivity and their "dramatic and systematic" simplification of reality [16]. In light of these critiques of geometric, "generic" data visualization metaphors, Cruz and others use semantic figurative metaphors that add context, interpretation, and nuance, avoiding "claims of finality" and harmful "essential" comparisons [6, 30].

A data collection and visualization approach centered around surveys and geometric shapes shapes how a community might use it to talk to one another. For example, we might talk about maximizing happiness or the connectivity of our social network. In other words, a typical visualization approach may leave us in the posture of analyzing its nodes and patterns, trying to control them. Meanwhile, we are left emotionally at a distance, leaving the tightness in our chest undiscussed and festering.

The analytic and extractive approach our data visualizations may have speaks to concerns that our practices of data science and visualization can have potentially violent consequences, sustaining "relations of domination and exploitation" [15]. In part, violence emerges through: historic power relations amplified in data science and visualization practices [9, 19, 23, 27], rigid categories and the abstraction of messy realities [24], the view of data as objective, a "given" [10, 14]. Instead of crafting life affirming futures, unexamined data visualization efforts can be deeply damaging.

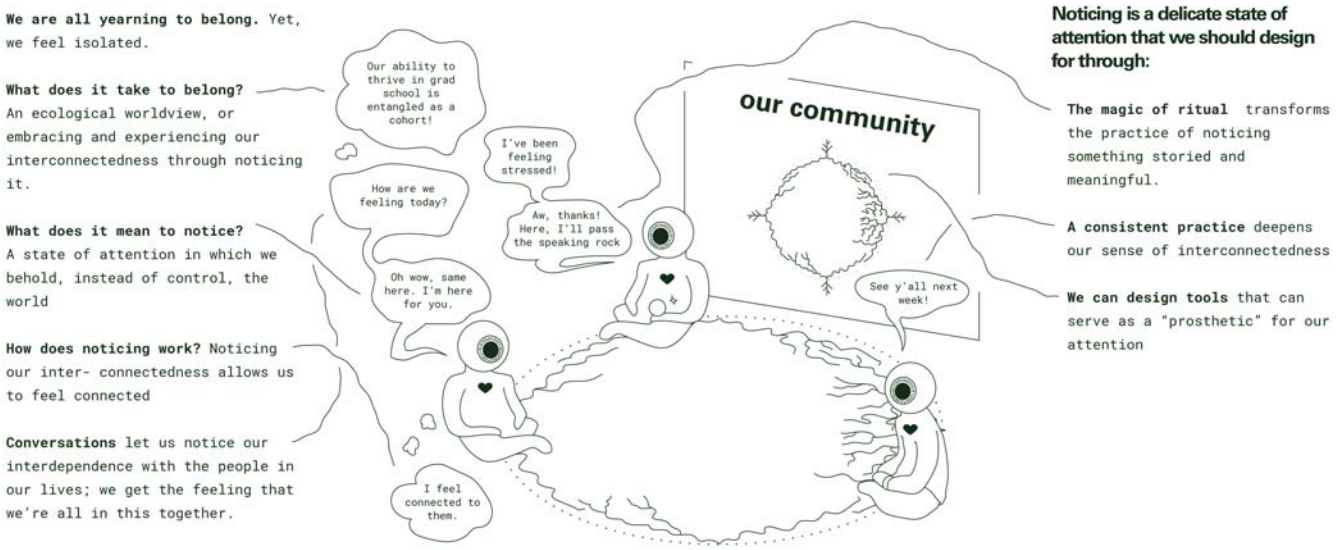

Fig. 2. Community conversations allow us to appreciate our interconnectedness, creating the conditions for belonging.

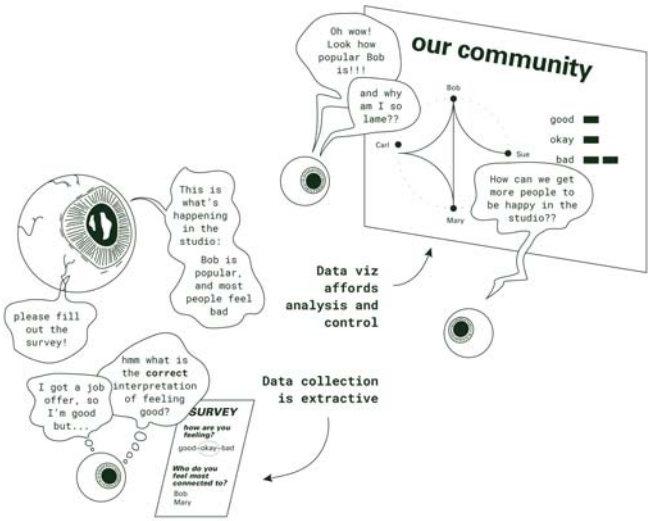

Fig. 3. Typical data visualization leave us engaging with the world in a mode of control.

2.2 Reclaiming data as situated and visualizations as ontological: Enabling transformative data visualizations

How does the way we think about data visualizations need to change to reorient our practices away from a tool of analysis and extraction? Two major theoretical shifts stand out: acknowledging the creation of data visualization as ontological, and (re)defining data as the phenomena observed by bodies.

2.2.1 Data visualization is ontological

In *Designs for the Pluriverse*, Arturo Escobar frames design as an ontological pursuit, writing that "all design-led objects, tools, and even services bring about particular ways of being, knowing, and doing" [12]. Data visualizations can change how we relate to the world, especially in our daily life; it's ontological. That is, data visualization impacts how we talk about the world, how we understand the world, and thus, how we relate to it.

For example, the hypothetical data visualization mentioned earlier shows a graph of how many people are "feeling good," leading to a conversation analyzing how to maximize that number (see figure 3). Subsequently, the conversation encourages us to relate to one another as isolated individuals. However, we can imagine different ways of collecting and visualizing data beyond creating conversations (and relationships) in the mode of extraction, analysis, and control.

2.2.2 Data is the phenomena observed by bodies

We argue that, as opposed to a single, objective way of sensing the world, different cultures and communities produce their own ways of knowing about and relating to the world. In sum, an observation is situated in who is sensing (their culture, etc.), a view otherwise known as situated knowledge [14]. In this view there is no "best" way of observing and creating knowledge about the world. Even deeper, we must open space for multiple ways of knowing about and relating to the world, or plurality [12].

Given the notions of situated knowledge and plurality, how should we redefine, or reclaim, data? In this research, we define data as the phenomena a body observes. We borrowed this definition of data from Timothy Morton's characterization of Object Oriented Ontology (OOO), the idea that no object is fully knowable. For example, one can only know about an apple by looking at it, juicing it and drinking it, or all of other ways (the phenomena, or data) a human body (and my tools) permit me to observe. However, one will never know about the apple in its entirety, the gesamtkunst-apple. What, and how, we can know about the apple always indicates who we are as an observer.

Even further, because any observer (human or not) never observes all of the phenomena from any given object, no one perspective can prevail as the "best" one. For example, a worm understands the apple by burrowing into it, and other ways we can't observe. In other words, OOO helps us define data in a way that doesn't privilege any single body or way of knowing about the world; it's plural.

Given these theories as a starting point, how must our data visualization practices change? In the words of Catherine D'Ignazio, we need to make visible those who are creating the data and who are represented by the data. In other words, we need to "bring back the bodies."

3 Methodology: How data collection and visualization changes when we bring back the bodies

By reframing data visualization as ontological, and data as observed phenomena, how might practices and theories change? We embarked on a research through design project, creating Tsuga Convictio, an experimental data collection and data visualization to support community conversations in the Carnegie Mellon School of Design masters' cohort.

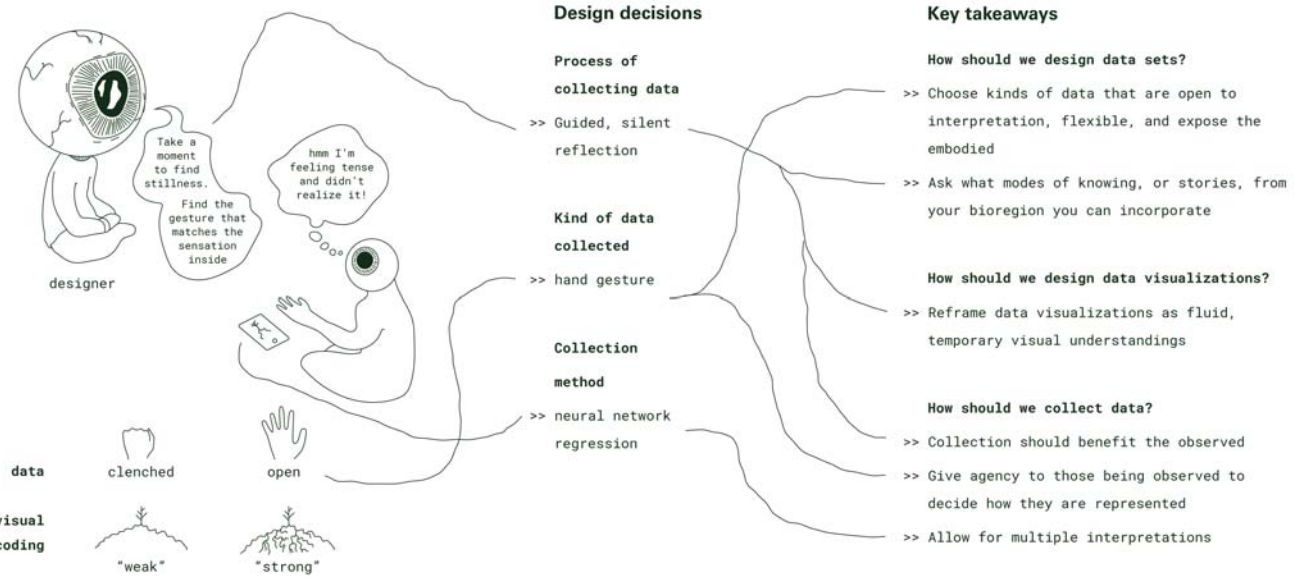

Fig. 4. Through building a data collection process for community conversations, we reveal key lessons about how we can alternatively design data collection processes.

The following section describes our major design decisions for both our data collection process and data visualization, pointing to lessons about how to visualize for the ecological and embodied. We further distill those lessons by answering fundamental questions about data visualization in section 4.

In this paper, we use the pronoun "we" to refer to the designers of the experiments and their implications to improve readability, though Ploehn, embedded in the community in question as a masters' student, led the design of all experiments (with continuing feedback from Steenson and Byrne).

3.1 Data collection prototype

We created a data collection process that invites participants to reflect on their felt experience in the masters' design community through the metaphor of growth of hemlock tree roots in Western Pennsylvania's forests. They reflect using a hand gesture of reaching or clenching, and can preserve their gesture as data using a phone's webcam, which uses a neural network regression to map hand movement to the "vivaiousness" of root growth (see figure 4).

We aimed to create a data collection process for community conversations that is reflective, poetic, and non-extractive. Through making this prototype, we discovered that creating data can be a process of noticing, observing, and listening by carving out space and time to notice how the body feels, incorporating ecological narratives. In our prototype, noticing the body (and what it feels) becomes the center of attention—that tightness in the chest, the nausea in the stomach. The scale of meaning is tied to a unique body, so multiple interpretations of the gesture are built into the framing of the data.

The following sections outline the process of creating the data collection process in detail.

3.1.1 Guided reflection as a way to collect data

The data collection process that best serves the reflective aspects of community conversation is a guided, silent meditation that uses meaningful movement, an opening and closing of the hand. We frame the collection process as a ceremony, using the story of old growth forests, situating the data as one person's perspective, an interpretation of their felt experience.

We (the data visualization designers) serve as a guide in our data collection process that centers silent reflection. Specifically, we introduce the way we are collecting data, saying something like: "Today we're going to reflect on our community experience through the lens of the tree's root. Like us, roots spread and grow when the body is strong; they don't grow and spread out as readily when the body is weak." We also frame the training of the neural network as reframing your hand gesture through the story of a root, saying: "Imagine this tree represents you. Hold up your hand to the camera. Imagine you're a tree root growing—reaching out into the soil for nutrients. Reaching, grasping, opening up. Imagine you're a tree root retreating, contracting. Slowly slowly close your hand, millimeter by millimeter. Contracting, closing, turning inwards."

With this explicit framing, we center our data collection process around reflection; centering the act of noticing our bodies and being present in conversations that foster belonging. In this way, collecting data opens space for people to connect with how they feel, expressing and recording it digitally as data. In our designed process, once the community members train the neural networks, the designer prompts the participants to reflect:"Take a moment to find stillness, meditating on this motion of opening and closing. Find the hand position somewhere here that matches how your body feels." Participants are then able to submit a hand position anywhere from closed to spread.

In addition, we found that a reflective data collection process can enhance conversations by emphasizing narrative and ceremony. Conversation is powerful as a kind of that ceremony, one that is a vehicle for belonging—to a family, to a people, and to the land" and marries the " to the sacred" [17]. Important in ceremonies is how they imbue the everyday with a story. Thus, we decided that the data collection process would tell the story of old growth forests through the cellular automata metaphor we developed (discussed in sections 3.2.2 and 3.2.4). Reinforcing this idea, conversations with peers about our data visualization prototype of old growth forests pointed towards a narrative-driven introduction to the meaning behind this complex visual metaphor.

3.1.2 Framing hand gesture as data

We chose a "reaching and clenching" gesture as the kind of data collected by our prototype because it's ambiguous and embodied characteristics help participants tap into their felt experience, maps well to a "growing and contracting" roots metaphor, and works well within a silent, reflective context.

Our design for a data collection prototype began with the premise that the act of creating and collecting data should be reflective, allowing people to connect with their body and give them the power to share those feelings in a way that felt true to their experience. Indeed, both

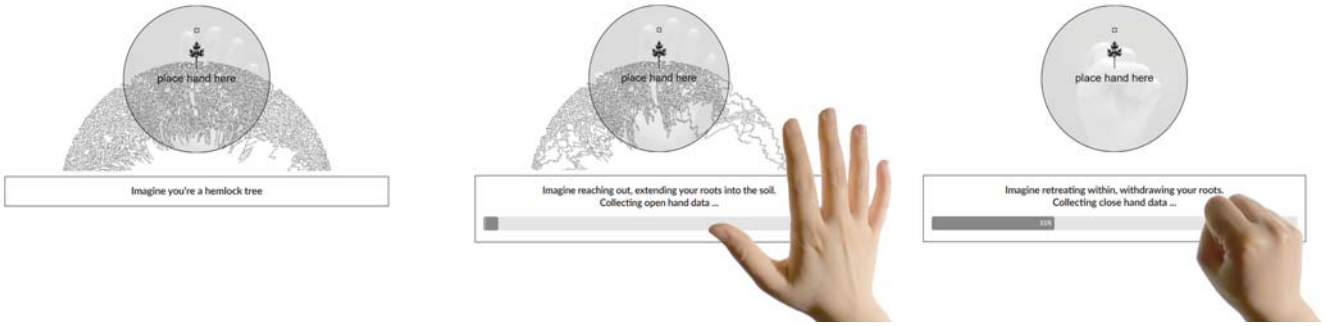

Fig. 5. Collecting gesture as data, through the metaphor of roots.

Neely and "Ambiguity as a Resource for Design" by Gaver et al., informed the following guiding principles for designing a data collection gesture [13, 22].

First, using the variables of the body in motion allow us to connect with our felt experience, reaching "a priori" meanings not fully captured through language [22]. Further, the variables of the body in motion can be used to help us feel the growth of roots. In "Soma Literate Design," Neely points out that the variables of the body in motion (rhythm, weight) create bridges to connect to the nonhuman [22]. Using these variables may help connect physical motion with the visual metaphor of roots that my visualization uses.

Second, ambiguity affords opportunities for design to encourage meaning-making. In "Ambiguity as a Resource for Design," Gaver et al. emphasizes the usefulness of ambiguity in design because it creates an interpretive relationship between us and designed objects, in which ambiguity requires us to create our own interpretations and meaning [13].

Incorporating ambiguity in a data collection process would not only open up space for multiple interpretations of the data collected, but also afford people to engage by providing their own meaning to ambiguous gestures.

3.1.3 Collecting gesture as data using a neural network regression on a phone

For our prototype, training a browser-based neural network on a phone was the ideal collection method. First, phones are more broadly accessible as compared to other forms of equipment, such as Leap Motion. Next, by training a neural net, each person can determine how they move, and thus how their likeness is captured as data. Neural networks allow us to open space for multiple interpretations in the act of creating data, giving agency to those represented by the data to determine how they are represented.

In creating a prototype for the data collection process, the choice of technology seemed consequential. In deciding what kind of technology we should use to record data, access was front of mind. By avoiding special equipment, we focused on building a data collection paradigm that would theoretically be usable by more kinds of people.

After settling on hand gestures as the kind of data to be captured (described in section 3.1.2), we sought a way to detect each person's hand movements as unique. We designed a neural network regression that detects gesture using Ml5.js and the phone's front-facing camera. To detect a specific hand's movements, we incorporated the training of the network with each participant's hand into the data collection process. During training, one opens and closes their hands in concert with the roots growing and closing. When the model is done training, the roots grow / contract with a hand gesture performed for the webcam. One can then move their hand to reflect with the roots, finally choosing a hand position, and a kind root growth, to capture as data.

3.2 Data visualization prototype

We created a prototype that visualizes data through a generative system forest, whose volume of root growth metaphorically represents the state of the community. In the prototype, each tree in the forest represents a community member, with their level of "vivaciousness" (submitted via our data collection prototype, dicussed in section 3.1) mapping to system behaviors that drive how enthusiastically each trees' roots grow, such as how many times a root can split (see figure 4).

The visualization was created towards helping us behold (instead of analyze) the world around us in the context of community conversations. Through making this prototype, we discovered that we can choose which data to visualize to guide a particular kind of to conversation emerge. Even further, when we create data visualizations, we can create visuals that can give a deep, visceral understanding of our data by choosing an ecological metaphor, brought to life with generative systems and metaphor. With practices like these, we can design data visualizations for conversations that help us develop a lens for noticing, or beholding the world our data represent.

3.2.1 Framing a data-driven conversation through interconnectedness and care

In our design, we aspired to cultivate belonging through creating visualizations that inspire a conversation of interconnectedness and care, with the data visualization designer framing the visualization as their own interpretation.

First, demonstrating care is a critical aspect of in-person conversations. In *Emergent Strategy*, Brown highlights the importance of in-person conversations as a ritual for building a sense of interdependence among people [4]. Next, conversations should be a place to experience the sense of interconnectedness; the people in conversation must feel an "intimate and authentic relatedness" [2]. In order to experience interconnectedness, we must speak its language of "connection and relatedness and belonging" [2]. In sum, the kind of conversation necessary for belonging is one where we can experience our interconnectedness, interpersonally and ecologically, using the language of care.

Second, in the context of the community conversation, the data visualization designer would describe why they made this particular kind of data visualization: "Like humans, trees can only thrive and grow old with the support of those around us. I've created this data visualization, imagining that we can help each other thrive like the old growth forests of Pennsylvania do." Their framing explicitly situates the data visualization in context, as a constructed interpretation.

3.2.2 The feeling of vivaciousness as data

In our visualization prototype, we named the the vague feeling of vivaciousness (thriving and/or retreating) as the kind of data we would measure, arbitrarily measured from a scale of 0 to 10). The ambiguity of such a measurement opened up space for each person to reflect on their body, and define for themselves what vivaciousness means.

We took the premise that the data we included in our designs should center around a person's felt experience in a community. Our ability to feel interconnected begins with reflection; reconnecting with the body is a precursor to being present with others [28]. In our design, centering data around felt experience may encourage reflection, connection to the body, and may improve our ability to be present with one another.

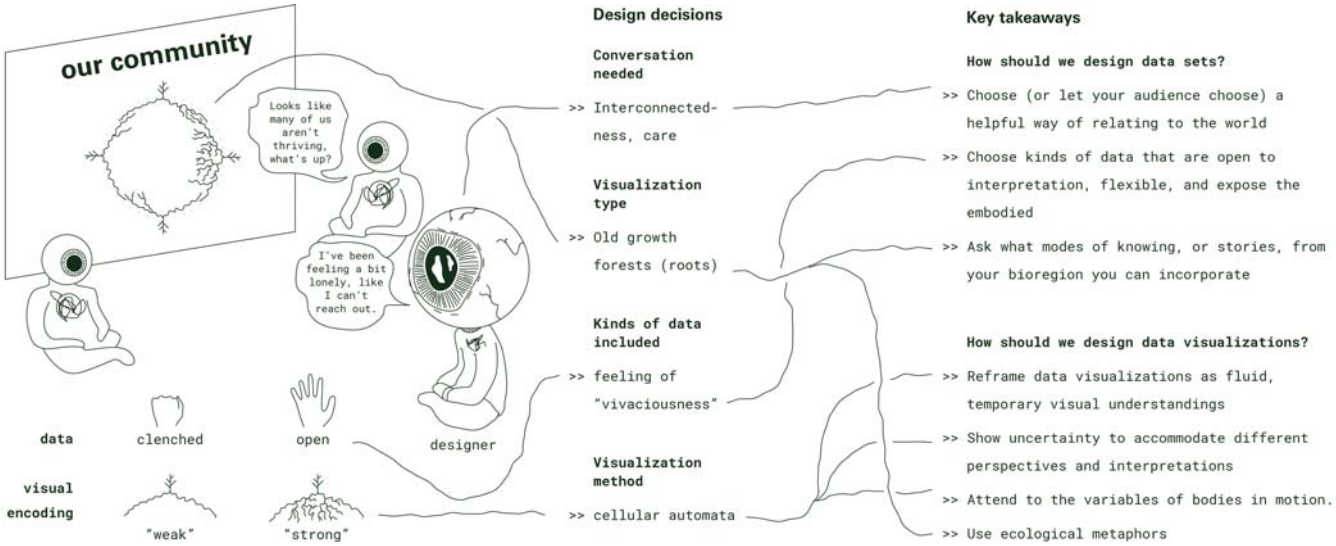

Fig. 6. Through designing a data visualization for community conversations, we reveal key lessons about how we can alternatively design data visualizations

To search for what aspects of experience we should spotlight in our prototype, we drafted a set of parameters based on the necessary conversations Block outlines for community belonging (possibility, ownership, gifts, dissent) and adrienne maree brown's guidelines for community organizing (asking for support) [2,4]. However, we found it hard to identify which aspect of a person's experience in a community was the "most important" to build. Each aspect felt too prescriptive of the kind of reflective experience one might have.

Our trouble lie in the rigid structure we aimed to impose on felt experience. To avoid the danger in rigidly structuring information, visualizations must use models of information that are explicitly flexible. In designing for the felt experience, then, the data categories should be malleable. Odell critiques the use of categories because they beget invisibility, collapsing a complex and blobby self [25]. Because rigid data categories collapse our identities, the need to only include kinds of data that can accommodate multiple interpretations became clear.

What kind of data can accommodate multiple kinds of interpretations? Embracing the idea that the data type we use should be flexible, we looked to the set of possible root visualizations in our prototype (described in section 3.2.4). Our explorations revealed was a commonality between humans and hemlock trees: the sense of thriving and retreating. In light of this simple and meaningful relationship, the idea of prioritizing certain aspects of experience was again reinforced as prescriptive. What was important in this conversation was reflecting on how the body feels, whether it was growing or retreating, whatever that means for the individual.

3.2.3 Using old growth forests of Western Pennsylvania as a metaphor for visualization

We chose Hemlock trees, critical in the old growth forests of Western Pennsylvania, as a visual metaphor for our data visualization prototype, opening up opportunities to connect to—and behold— local ecologices.

First, reconnecting with the ecologies around us is key for feeling a sense of belonging and connectedness—to feel the magic in the banal. Adrienne maree brown writes about community transformation in *Emergent Strategy*, emphasizing that "authentic and generous" relationships with people and the land they reside in is necessary for survival:

"Do you understand that your quality of life and your survival are tied to how authentic and generous the connections are between you and the people and place you live with and in?" [4].

To choose which ecological metaphor to use, we explored Western Pennsylvania's bioregion, the Western Allegheny Plateau. Wohlleben describes the unique and incredible characteristics of old growth forests, which were vital to early humans (indigenous and settlers) and the health of the landscape (water), but are increasingly vulnerable in a warming climate [31].

What is striking about Wohlleben's description of old growth forests is their similarity to human communities. Old growth forests physically demonstrate the concept of community resilience through interdependence [31]. Like humans, trees can only thrive and grow old with the support of those around them. Together, they create the conditions within which they can thrive, such as sharing nutrients through their roots [31]. Inspired by Wollheben, old growth forests became the ecological metaphor we would use in our visualization. We imagined our own communities could help each other thrive like the old growth forests of Western Pennsylvania do.

Specifically, we chose to focus on Hemlock trees, Tsuga canadensis, prominent in the old growth forests of Western Pennsylvania and critical to the landscape. Hemlock trees are historically and ecologically important.

In an effort to deepen our appreciation and understanding of how the Hemlock trees of Western Pennsylvania live, we began researching old growth characteristics, visiting Cook Forest. With this more robust understanding, we created a palette of qualities of old growth forests, working to decide how to map human reflection onto these attributes and build out a hemlock tree metaphor digitally with cellular automata, which we describe in section 3.2.4.

3.2.4 Using cellular automata to visualize data

In our prototype, we used a generative system with cellular automata to visualize data, based on a visual metaphor of the sharing nature of root systems in old growth forests. In creating this prototype, we learned data visualizations created with generative systems can give us a feel for the data, to viscerally understand what that data represents.

Generative systems, such as cellular automata, model behavior according to rules that, when you map values to them, can show emergence. Using systems like cellular automata made sense to use because they enable us to digitally model, and appreciate, root growth. Unlike the one to one mappings of visual characteristics to data that you find in visualizations such as bar charts, mapping data to rules in generative systems produces results that are emergent.

First, we developed the metaphor of tree root systems into a plan that could be translated into a generative system. In this metaphor, trees represent individual people. Each tree grows roots. We designed the growing process by deciding what kinds of behaviors drive roots to

Fig. 7. The submitted data is visualized as trees growing roots in a forest.

grow (or not), evaluating these behaviors through a visual language of care. For example, the trees' roots explore their surroundings until they meet a root of another individual, connecting their root systems, representing the idea that we are reaching out for connection.

We tested our root metaphor by building a generative system, specifically using cellular automata. Cellular automata are discrete computer models in which cells, or independent actors, behave according to rules based on their neighbors. In our prototype, each root is an independent actor. Each tree grows roots over time, or "frames." Every frame, each root will grow and/or produce a new root based on behavioral rules. Each root "looks" at adjacent areas and randomly grows into one viable area. Roots will not grow into areas that have other roots in them or don't have nutrients.

In building the prototype, we had to balance how these behaviors played together, discovering some implications for designing data visualizations with generative systems. Some sets of variables caused some roots to impede into other tree's growth areas, others produced sparse root networks that struggled to grow. For example, certain roots are "choked out" by other more expansive root systems, literally "taking up too much space." We tuned these variables in the system, creating a little world of trees. Again, crafting these root behaviors gave us an appreciation of the mystery and magic in how these invisible structures grow and support life beneath our feet.

As we developed rules for root growth, it was difficult to know which combinations of behaviors caused what kind of root growth unless we simulated the system's conditions. Even running these simulations produced wildly unexpected results. To grapple with designing this system then, we used a typical tool in generative systems, visualizing all possible designs under different behavioral rules. In exploring the design space, our focus turned towards searching for meaning in these emergent patterns, another implication for visualizing with generative systems.

We generally found that certain root growth behaviors mapped to how densely and strong the roots grew. We created ranges for each root growth behavior that, together, would demonstrate how strong of propensity for growth a root has. We could map these ranges to one scale that made roots grow more or less strongly. Then, this scale could be assigned a data input. As discussed before, the data input we used was a community member's feeling of "vivaciousness" as data, arbitrarily mapped to a value of 0 to 10 (outlined in section 3.2.3).

In our prototype, the rules of behavior (how often a root splits) become abstract in the emergent visual encoding ("strong root growth"). In visually encoding the expressive quality of "strength," the emergent properties of growth are prioritized over specific mechanisms. Although, exploring visualizing data directly with rules in a generative system, as opposed to indirectly through their emergent properties, is worth exploration.

Because cellular automata show meaning through emergence, the visuals they produce embody uncertainty and ambiguity, carving out space for multiple interpretations and demonstrating the fluid nature of knowledge. The visuals produce ambiguity in a way that makes art "...profoundly ambiguous, and thus "powerful" because "we can't tell whether it's telling the truth or lying" [21]. Through their ambiguous appearance, the cellular automata roots break from a standard geometric grammar of graphics that reinforce a sense of truthiness in the viewer [16].

Even more, because they simulate growth in time and space they bring to life visuals, we get a visceral understanding of the data. A system like cellular automata can model the natural growth of roots, which not only allows us to feel what reality the data represents, but also allows us to appreciate and notice how the trees around us care for one another. In other words, data visualizations created with generative systems can give us a feel for the data, to viscerally understand what that data represents.

4 Discussion: New theories and practices for data visualization

In designing an experimental data collection process and data visualization (as discussed in the previous section), we reveal lessons about how to visualize for the ecological and embodied. In the following section, we further distill those lessons by addressing fundamental questions designers explicitly (and implicitly) answer when they craft visualizations. These practices and theories are non-exhaustive, but they already show the potential for turning data visualization away from a tool of control towards one of transformation. We divide our discussion into three separate, but interrelated elements associated with designing data visualizations: data sets, data collection processes, and data visualizations.

4.1 How should we create data sets?

Our explorations reveal an imperative to design data sets towards exposing how the data included (and not included) reflects one perspective, one way to relate to the world. New methods for designing data sets begins with redefining data as the phenomena observed by bodies, which implicates the observer's perspective in the creation of data. Consequently, data sets reflect a perspective, a lens of looking at the world. Thus, when we choose what data will be included in our exploration, we decide a mode of knowing, possibilities for relating to the world.

4.1.1 Choose (or let your audience choose) a helpful way of relating to the world

As discussed in section 2.2.1, data visualization impacts how we talk about the world, how we understand the world, and thus, how we relate to it. Whether intentional or not, the data visualizations we design actively shape—and are shaped by—our worldview, or how we see the world.

Thus, when we design data visualizations, we should attend to the kinds of worldviews we are embracing. For example, in Data Feminism, D'Ignazio and Klein assert that designers should examine "for whom" we are creating data visualizations, and that "what is counted counts;" what data we include (and how we collect it) reveals what's important to examine for whom [9]. Bringing these principles to life means that, when we create data sets, we should examine what kinds of relationships and worldviews are emerging. Even better, we can actively strive towards embracing the kind of worldviews that produce equitable and life-affirming futures, using them as north stars to help us choose the kinds of data we attend to.

In the case of our project, our north star was fostering a feeling of belonging. Specifically, we found that embracing and experiencing an ecological worldview would is fundamental for belonging, and feeling a sense of interconnectedness and relatedness is key. Thus, focusing on including data about our felt experience seemed key; noticing as a step towards feeling connectedness. When we chose to look at our communities through the lens of vivaciousness, we are choosing (and imposing) that particular way of thinking about reflection and community (as opposed to choosing stress level, for example).

4.1.2 Choose kinds of data that are open to interpretation, flexible, and expose the embodied

Abstracting living organisms can often be a violent act, as discussed in section 2.1.3. Part of the issue lies in the simplification that happens when we represent a messy world as simple data. We unconvered the following methods to address simplification.

Keep the body visible through flexibile categories and models of data In "Rhizome" (the first chapter of A Thousand Plateaus: Capitalism and Schizophrenia),Guatarri and Deleuze warn against structured representations of information [8]. Indeed, data visualizations are structured. To encode information visually, even in the most flexible models of visualizing, a structure is required. The structure in a data visualization is, in part, a conceptual models with data linked to visual encodings. Thus, to avoid the danger in rigidly structuring information, visualizations must use models of information that are explicitly flexible.

Keep the data open to interpretation through ambiguity Legibility through specificity is another issue in data that can lead to stagnation at best, and violence at worst. As Jenny Odell writes in Designing for the In-between:

"We should object to [maximizing legibility in] design, because a world with no in-between does harm on every level...It does immediate harm to those who try to cross borders and boundaries, like LGBQ, trans, and immigrant folks. And it does harm to all of us by depriving us of the exchange of ideas and perspectives that are truly outside of our own. A world with no in-between is like an anemone with no fish to do a wiggle dance for it. It can't breathe" [25].

Ambiguity affords privacy through lack of legibility and opening up space for interpretation. Along these lines, Gaver et. al write that ambiguity creates an "interpretative relationship" because "ambiguous situations require people to participate in making meaning" [13].

Designers can use ambiguity to make visualizations flexible to multiple interpretations. Further, ambiguity may encourage viewers of the visualization to engage more deeply with it through the act of constructing an interpretation.

Flexibility and ambiguity allows us to embrace the body. In Data Feminism, D'Ignazio and Klein define "elevate emotion and embodiment," qualities that are often ignored or obscured as ways of understanding the world through data. We can avoid abstracting or obscuring emotion and embodiment through choosing kinds of data that are both ambiguous and flexible. In our research, we chose to collect the "vivaciousness" we feel as data, arbitrarily mapped from a scale of 0 to 10. Vague on purpose, this kind of data encourages us to reflect and assign our own meaning to that scale.

4.1.3 Ask what modes of knowing from your bioregion you can incorporate

Ecological metaphors can help us develop ways of knowing that are beneficial to us and to those who use our data visualizations. Although it is vital to behold ecological relationships and coexistence at many levels of scale, drawing from the bioregion offers an experiential path towards ecological belonging and stewardship. Reconnecting with the ecologies around us is key for rekindling a sense of belonging within them. To form authentic connections with the land, we can seek lessons from the ecologies around us, from our bioregion. Therefore, we should embrace ecological ways of knowing and metaphors that help us appreciate one another and the land.

In our project, appreciating our interconnectedness and interdependence in community was critical. Thus, we chose to use the hemlock trees that live in old growth forests of Western Pennsylvania as a visual metaphor because we can learn volumes from them about living in community. In particular, they share nutrients through their root systems, ensuring each tree can thrive equally. Roots demonstrate in a physical, tangible way the interconnectedness of members in a community.

Using ecological modes of knowing also help us present our knowledge as situated, avoiding a "god view." Using modes of knowing from our bioregion gives a data visualization context. Because the hemlock trees are critical organisms in the forests of Western Pennsylvania, where this research was conducted, they offer a rich, potent narrative that grounds our data visualization in the bioregion it was created. Further, although one kind of organism is spotlighted in this project, exploring webs of related organisms (such as the relationships between trees, mycellium, and birds) provides a potentially fruitful path of exploration that extend concern beyond a bioregion.

Finally, those modes of knowing contain stories of the organisms they come from. We should use those stories to guide our data collection process and the conversations around the visualizations we make with them. These ecological stories help us contextualize data, but also help us behold ecological ways of knowing. For example, our designed collection process tells the story of old growth forests through the a metaphor of root growth. Even further, the histories and mythologies are a

4.2 How should we collect data?

Our research demonstrates a need to collect data towards giving those we observe a sense agency and privilege in the experience. It begins with a refocusing of the data collection process towards those being observed, maximizing the amount of agency they have in how they are represented through data. More deeply, those represented through data should benefit from the act of collecting data, even participating in how they interpret and observe the data they are creating. With these practices, data collection can be refocused towards reflection, as opposed to analysis.

4.2.1 Give agency to those being observed to decide how they are represented

Data visualization designers have the ability to observe (or create data about) someone, which is an exertion of power. In The New Dark Age, James Bridle writes that data "sustains and nourishes uneven power relationships: in most of our interactions with power, data is not something that is freely given but forcibly extracted—or impelled in moments of panic" [3]. When data is created about us, we are represented a certain way, and can be acted upon (and possibly controlled) through those data. Each new data point is like another knob or lever that someone can twist or pull for their ends.

In this project, opening space for agency in the data creation process seemed to be part of the antidote in equalizing the power imbalance between observer and observee. One way agency can be given is through deciding which data to share with whom. In our project, we strove for giving the observed agency in deciding whether to share their experience through data. Another form granting agency in a data collection process is through the act of creating data. In our designs, as opposed to a passive data collection, participants create data through their own gesture, articulating exactly what can be captured and how.

Finally, we can give agency back to the observed by giving them agency to ascribe their own meaning to their data at the point of collection. In our project, because "objective" scales for expressing emotion don't exist, each participant has the ability to create their own. They each decide what their particular expression of emotion means through deciding exactly what kind of hand gesture maps to the each end of the scale.

4.2.2 The data collection should benefit those you're observing

In Data Feminism, Klein and D'Ignazio urge us to examine "for whom" our data visualization projects are for [9]. In particular, asking who benefits from a data collection process reveals a largely lopsided relationship. We often design collections in which we extract information from those we observe, offering little consideration for how the process might also serve them. What can be done? Money is certainly an option, but there are more deeper opportunities here.

We can consider ways our data collection process might include participants as observers too, not just as observees to be extracted from. For example, a microbiome research project can involve patients in making sense of their own samples, providing them with interpretations of their microbiome for them to appreciate. Taken to the extreme in this project, we designed a reflective data collection process purely for the

benefit of the observee (not the observer). With the goal of supporting reflection, then, we had to rethink ways of collecting data away from extraction, which meant designing a lens of appreciation, not control.

Our efforts began with repositioning the data visualization designer as guide—instead of a leader—of the data collection and subsequent conversation about the visualization. Next, all experiential aspects of the data collection process were chosen to serve a healing reflection, instead of efficiency and logic. First, reframing the context of data collection as a ceremony, using the story of old growth forests, evokes a sense of "magic in the mundane" (instead of a sense of efficiency) [17]. Next, reflection meant connecting with the felt experience of the body, instead of logical evaluation. By tapping into the variables of the body (rhythm, heaviness, etc.), data collection can become a tool for reflecting and capturing felt experience [22].

4.2.3 Allow for multiple interpretations of your collection

As mentioned earlier, using flexible and ambiguous kinds of data helps afford multiple interpretations, which is key for avoiding the kind of violent abstraction that silences, simplifies, or obscures messy realities [8,9,24,25]. To fully embrace this principle, the data collection process must also support multiple interpretations.

Even further, we can focus on the body, collecting gestures and other ambiguous forms of data to craft flexible categories. In our project, we used a neural network to let people map a hand gesture from closed to spread to portray their felt experience.

Finally, we can let each participant decide the "scales" of data mean. By using several vague words to describe each end of the scale, such as reaching and retreating, meaning is up for interpretation. By letting users decide what the scale means, there is space for many more interpretations that might have otherwise been invisible, or lost.

4.3 How should we visualize data?

Our research reveals the need to design data visualizations that give us a feel for the data, and the perspective of the designer. It begins with explicitly reframing data visualizations as temporary and bounded in perspective, though showing uncertainty using ambiguity. Even further, we can design data visualizations for deep, visceral meaning by using a palette of "body in motion" variables (heaviness, rhythm, etc.) and ground our visualizations in ecological context by drawing from our bioregion.

4.3.1 Reframe data visualizations as fluid, temporary visual understandings

As discussed before, Using flexible and ambiguous kinds of data is key for avoiding violent abstraction that simplifies or warps complex realities [8,9,24,25]. Given a flexible kind of data, one way to embrace this temporality and fluidity in our data visualizations is to explicitly frame our data visualizations as such. In our project, the data visualization designer frames their creation it as my own perspective in the conversation, saying: "I've created this data visualization, imagining that we can help each other thrive like the old growth forests of Pennsylvania do."

4.3.2 Show uncertainty to accommodate different perspectives and interpretations

As mentioned in the previous section, visualizations must be framed as temporary instances of what we know, limited in perspective. Amplifying this notion, visualizations can also be flexible, accommodating multiple perspectives, keeping all kinds of bodies and perspectives visible.

Beyond an explicit statement by designers, data visualizations can demonstrate this flexibility visually. As mentioned earlier, ambiguity is key for designing for multiple interpretations [13]. Ambiguity in data visualization may help people think about the broader community, ask questions, and engage. If enough nuance and uncertainty is imbued within a visualization's style, it can clearly come across as a pathway into a particular view into the world–especially if the visuals used add context (who made it, etc.). This means multiple data visualizations, using different models of knowing, can sit together as doorways into different views of the world.

In our project, how could we visually imbue ambiguity and uncertainty in our visualizations of our community members as hemlock tree roots growing in a forest? We use generative systems because they offer a viable option of exploration. In particular, we built a visualization prototype using cellular automata roots. Cellular automata are discrete computer models in which cells, or independent actors, behave according to rules based on their neighbors.

As opposed to the one to one mappings of quantitative values to visual attributes you might find in a traditional data visualization, cellular automata models behavior according to rules that, when you map values to them, can show emergence and patterns. Generative systems like these are inherently unpredictable, visually demonstrating uncertainty. Generative systems offer a pathway to a new grammar of graphics away from "truthy," disembodied geometries towards fluid, visceral behaviors.

4.3.3 Attend to the variables of bodies in motion

Neely writes that the soma - the felt experience of the body (the tightness in the chest, and the nausea in the stomach) is the fundamental constant of all experiences. Specifically, Neely updates Samuel Todes' Body and World, asserting: "The knowable world. . . is the human body's word, and only those elements that have some kind of affinity to the human body can [become known]" [22].

If we primarily understand the world through our felt experience, how can we design data visualizations that resonate deeply and meaningfully with it? Neely states "If the goal is to make them known, the designer has to offer a primary interaction or secondary metaphor to foster the knowing" [22]. These metaphors have to account for these previous physical interactions with the world to become meaningful in the body. Neely offers a set of example vocabulary for soma literacy, including terms such as rhythm, weight, and agogics [22]. Specifically, we can draw from a palette of variables of the "body-in-motion" in both how we conceive of data collection and visualization can become deeply known, felt in our body [22].

In our prototype, we chose cellular automata roots as a visualization paradigm, in part because generative systems give us the opportunity to incorporate the variables of the "body-in-motion." Specifically, they can be used to produce animated simulations of moving, digital organisms. As opposed to the one-to-one mapping of quantitative values to visual attributes you might find in a traditional data visualization, generative systems show patterns and emergence in a lively way, which may give you a feeling for the data; a deep somatic understanding.

Whereas data visualization designers may argue for a greater graphical literacy, we argue that data visualization designers should learn techniques for creating graphics such as using generative systems that attend to the body's way of knowing through motion in physical space. The more designers can use these bodied variables to convey patterns, the more deeply, profoundly, and viscerally we will understand them.

4.3.4 Use ecological metaphor and story

As mentioned before, our data visualization practice should embrace ecological ways of knowing and metaphors because they help us appreciate one another and the land and contextualize our designs.

In terms of visualization, ecological metaphors also help us design visualisations that are deeply, viscerally meaningful and open to multiple interpretation. First, ecological metaphors involve living organisms moving in time and space (the spider spinning a web, a tree growing twisting roots). These visual metaphors offer us embodied variables abound, making them very useful for giving us a feel for data. Further, using these metaphors and their embodied metaphors offer a pathway for deep connect, to the people in our community and the ecologies these metaphors represent:

"By directing attention to the often-overlooked/assumed/ignored soma tier of experience, I am claiming that we open a window to a fundamental aspect of human experience. Empathy for the Other (human and non-human), discovered through and understood at this most base level of the pushed and pulled, tossed and turned, enkinaesthetic

(social) body-in-motion, is potentially the most intimate interaction that can be designed. The soma experience is so universal and so base that it holds the potential to cross gender, age, and socioeconomic divides, divides that must be confronted if meaningful cultural/social transition is to be accomplished" [22].

As mentioned earlier, we used hemlock trees that live in the old growth forests of Western Pennsylvania as a visual metaphor in our design because their nutrient sharing roots demonstrate in a physical, tangible way the interconnectedness of members in a community. In our prototype, we visualize the growth and interlocking movement of roots over time, bringing this powerful metaphor to life in a visceral way.

Second, ecological metaphors help our visualizations accommodate multiple interpretations of data. When we use ecological metaphors in our data visualizations, they resist rigid boundaries, opening doors to compelling methods of visual display that embrace multiple perspectives of the world [25]. In our data visualization, feelings of vivaciousness map to the vitality of roots growing. Displaying vivaciousness visually through the strength of root growth provides a gradient of meaning, porous and open to interpretation.

5 Future work

Given a reframing of data visualization as a tool for imagination, engagement, and transformation, our research offers a step towards several new directions for deepening a transformative data visualization, described in this section .

Developing a new grammar of graphics for data-feel with generative systems Our project underlines generative systems as a compelling tool for visualizing data. Using simulations, models, etc. to visualize data is not new, but would benefit from being developed into frameworks that highlight what different kinds of generative systems afford in visualizing data. Specifically, generative systems could be developed into a possible alternative grammar of graphics.

Collect metaphors grounded in bioregions Using ecological metaphors is a compelling trend in visualizing data. For example, Cruz et al. uses tree dendrology to visualize the demographic composition of the United States [7]. To build on this trend and enable more designers to leverage an ecologically-driven vsual language, metaphors (and their associated stories) from a multitude of bioregions could be collected.

Exploring machine learning techniques for detecting the body in motion variables and creating custom scales As machine learning tools, such as Ml5.js and Teachable Machine, enable increasing numbers of artists and designers to incorporate AI into software systems, techniques to instrumentalize them for data visualization could enable designers to accomodate a multitude of differences in

Explore new theories practices necessary to embrace the ontological nature of data visualization While this research reveals several implications of using an ontological approach to data visualizations, more possibilities than solutions emerge. The need exists to reimagine how data visualizations might be designed for different contexts (particularly culturally) and ontologies.

6 Conclusion

This research offers a step towards a practice of crafting visualizations that contribute to critical conversations. When we look at the failings we have in the kinds of conversations that emerge from our data visualizations, the need to address how data visualization impacts how we relate to the world is critical. We must not only develop new practices that bring the bodies back to data visualization, but embrace how data visualizations can be a tool for beholding the entanglements we have world around us, creating the conditions for belonging we yearn for.

What can a good data visualization do? Or, what can be accomplished with ontological data visualization? Good data visualizations enable us to have transformative conversations by holding space for multiple ways of knowing about the world (ambiguity), giving us a chance to viscerally understand, or have a feel of, the world, and by giving us a visual record of the intangible patterns that surround us. Good visualizations can only be created by thoughtful designers, those who reflect on their work, have humility in their limitations, and commit to their responsibility as a designer in making meaning.

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