

High Water Pants: Designing Embodied Environmental Speculation

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Fig 1. High Water Pants mechanically shortened showing a cyclist is in an area in Seattle that will be impacted by sea level rise in the future (left) in the ‘down’ position (center) and showing the microcontroller soft circuit (right).

ABSTRACT

In this paper, we present the High Water Pants: speculative wearable technology which makes climate change tangible for everyday cyclists. The pants work by mechanically shortening when a cyclist wearing the pants enters an area of Seattle, USA, which is projected to be impacted by sea-level rise in 30-80 years. This interaction ‘bends time’ by allowing cyclists to feel future climate change data in the present. First, we discuss the research through design process of creating the High Water Pants including foundational research, a description of the design concept and results of a preliminary study with the pants. Second, we discuss three implications of the pants for human-computer interaction

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(HCI): (1) they offer the concept of a ‘present/future’ paradigm for embodied speculation, (2) our research process demonstrates how to successfully involve more-than-human perspectives, and (3) we articulate how the High Water Pants respond to shifts in HCI’s framing of sustainability.

Author Keywords

Embodied Speculation; Sustainability; Wearables; Research through Design; Speculative Design; Cycling

CSS Concepts

Human-centered computing–Interaction design process and methods

INTRODUCTION

Our interest in the intersection of cycling and climate change is situated within Biggs’ commitment to everyday cycling—they have been riding bikes in Seattle, USA, for the past thirteen years for a plethora of reasons including racing, commuting, touring, delivering pizza and socializing. However, in Seattle, the last few summers posed risky conditions for bike commuting due to air pollution from forest fire smoke. This smoke, which can be attributed in part

to climate change, made Biggs newly aware of how climate change could impact their cycling practice. It also made them realize that, due to everyday exposure to the elements, everyday cyclists will be uniquely impacted by climate change—it could pose threats to mental and physical health, mobility and sense of freedom.

However, due to the natural fluctuations in weather and the generational time scale of climate change, it is hard for everyday cyclists to tangibly grasp or reliably pinpoint the manifestations of climate change. The complexity of feeling climate change is elucidated by Timothy Morton's terming of climate change as a *hyperobject*—a phenomenon that operates at radically different temporalities than human scale ones we are used to [33]. According to Morton, hyperobjects are at once ubiquitous and ineffable, present but never the totality of an occurrence. This presents a challenge: if climate change is a hyperobject, how might one feel it or understand it tangibly at the local and every-day scale of human perception—the level in which cyclists understand climate through their daily practices? As a result, in order to address recent calls in HCI to create meaningful urgency around climate change [26,27] it might require making climate change more immediate and tangible at the scale of everyday life and personal experience.

Therefore, we present the High Water Pants (fig. 1), a wearable, mechatronic cycling garment which seeks to situate climate change through its intersections with everyday cyclists and make it perceptible within their everyday practices. The High Water Pants work by mechanically shortening when a cyclist rides into areas predicted to be impacted by sea level rise in the future, giving a cyclist contextualized, subtle tactile cues about their future imbrications with climate change. **Ultimately, this research attempts to make climate change tangible through creating a speculative artifact which encourages everyday cyclists to notice, validate, envision and concretize their intersections with climate change.**

In the following we offer two contributions. First, we contribute a detailed description of our Research Through Design (RtD) process [18,47] which consisted of first person experiments, semi-structured interviews, speculative probes, and designing, building and deploying the High Water Pants. Second, we offer an accounting of the implications discovered through this RtD process which include discussion of (1) the potential of embodied speculative design which 'bends time', (2) investment in including voices and perspectives of non-human actors throughout our research framing, methods, and outcomes, and (3) ways that sustainability in HCI is being pushed forward through the High Water Pants. This RtD process was based on a combination of first-person research methods and insights from a small group of everyday cyclists, and, while we believe this project reaches in many subtle directions into the tangled web of intersecting factors impacting climate change

(class, politics, culture, economics, etc.) it is not meant to be read as universal or total.

CLIMATE CHANGE IN THE PACIFIC NORTHWEST

While difficult to perceive, climate change is in progress and already impacting cyclists, as they start donning particulate masks in smoky summers, for example. Climate change will continue to transpire at an accelerating pace if we don't act radically to reduce CO2 emissions. According to *The Puget Sound State of Knowledge Report* [31], a comprehensive outlook on climate change impacts expected for the Puget Sound (one of the main bodies of water surrounding Seattle), the first tangible signs of climate change are becoming noticeable and the acceleration of impact is projected to increase in the next 30-60 years. This report explains how average annual temperatures have warmed 1.3 degrees Fahrenheit in the last century, and summers are projected to warm by 4-6 degrees Fahrenheit by 2050 (relative to 1970-1999). Sea levels have already risen 8 inches in the past century, are projected to raise another 10 inches by 2050, and an additional 28 inches by 2100 by moderate estimates [32]. The impacts of climate change on the Pacific Northwest aren't fully known, both due to the complexity of compounding factors leading to climate change impacts, and the unknown aspect of CO2 emissions in the coming years, but the Pacific Northwest can expect continued smoke from large-scale forest fires, increased nuisance flooding and chronic inundation, increase in allergens and desynchronizing of annual biological events (to name just a few expected outcomes) [30].

RELATED WORKS

The High Water Pants, as a speculative wearable provocation which make climate change tangible for everyday cyclists, intersect with a history of cycling as a sustainable and embodied urban transportation, as well as traditions of sustainable HCI, speculative design, and tactile, non-screen-based, wearable technologies for cyclists.

Urban Cycling and Sustainability

The High Water Pants are in dialogue with a larger cultural context of cycling as a sustainable and embodied form of urban transportation. Cyclist-friendly cities have long been idealized by urban planners as ways to reduce pollution, traffic and carbon footprints of cities [3,22,43]. Cycling is also often studied for how it offers a sensory rich, embodied and tangible experience of a city [14,23,46]. In this project we leverage the embodied/sensorial aspects of cycling as transportation to invert the aspects of cycling that are idealized as a sustainable practice by showing how it might become unsustainable (as a lifestyle) as climate change advances.

Sustainable Human Computer Interaction

In order to investigate these the future (potentially less sustainable) intersections of cycling and climate change, the High Water Pants use the tools of HCI (microcontrollers, big data, live GPS) to express tenants of sustainable human-computer interaction (SHCI), a branch of HCI established by

Blevis' seminal paper, [5], and again reinforced by Disalvo et al. survey of SHCI in 2010 [13]. The field of SHCI seeks to address sustainability through critiquing consumption and production, and/or creating technologies that persuade people to change their unsustainable behaviors through sensing environmental impacts like air pollution, or communicating issues around sustainability (to name a few approaches). However, as mentioned by several HCI scholars in recent papers, these approaches are not urgent or radical enough to actually grapple with the crisis of climate change [26,27].

Human and Non-Human Relations in the Anthropocene Era

In recent years, some focus in SHCI has shifted to be urgently aligned with climate change as well as seeking adaptive, post-capitalist, and post-anthropocentric approaches [12,26–29,45]. Some recent SHCI researchers acknowledge the Anthropocene era and seek to break down dichotomies between human and non-human actors through 'collaborative survival' [28] and designing for interspecies interrelationships and a multi-species world view [24,39,45]. The goal behind collaborative survival and design for multi-species interactions is to sensitize humans to their connections to ecology, acknowledge limitations in growth and production and seek harmonious relationships with the natural world.

In Liu et al.'s paper about collaborative survival, they claim to be designing for interspecies resilience between human and mushroom, borrowing a premise from Anna Tsing's book *Mushroom at The End of the World* [49]. This project offers a new framework for thinking about ways of designing for sustainability which are adaptive—meaning, resigned to the experiencing and mitigating impacts of climate change. They cite technoscience scholar Donna Haraway's recent call to, "stay with the trouble" [20], which they interpret as, "a call to look at, notice, and respond to the destructive processes we may prefer to ignore" [28:2]. We were inspired by and take up this charge with the High Water Pants as well.

Speculation

The nature of the High Water Pants, which stimulate imagined scenarios about future of sea level rise, make them a speculative artifact, where speculation is broadly defined as a way of envisioning possible futures or alternative presents [2]. The pants respond to and borrow from two subsections of speculative design: embodied speculation [1,7,15] and material speculation. The pants are a synthesis of these branches of speculation in that they use a material artifact for actual reflection which enables embodied speculation by dovetailing with each cyclist's unique history of situated and embodied knowledge about Seattle, opening opportunities for each cyclist to speculate from their own history of practice.

Material Speculation

Material speculation "utilizes physical design artifacts to generate possibilities to reason upon" [50:97]. It acknowledges how experiencing a physical object can

embody and inform speculations by inserting near, but alternative worlds, materially, into the existing world. "*In material speculation, it is making the counterfactual into an actual artifact that crosses the divide between the actual and possible worlds*" [50:101]. Wakkary et al. suggest that while from the stance of literature's possible worlds theory, possible and actual worlds remain separate, in material speculation, objects are able to bring a sliver of a possible world into the actual world via an artifact. While some material speculations are designed to be counterfactual [41,42], unaware [38], and slow [36], the High Water Pants are something of a future-factual object, as they are less about an object materializing a glimpse into another possible world adjacent to ours, but about experiencing the future of our world (in light of climate change) into the *felt* present to speculate about the ramifications of that future. We will unpack this future-factual quality further in the discussion.

Embodied speculation

In addition to relying on the actual and material artifact of the High Water Pants, they also utilize embodied speculation—speculation which acknowledges a need for speculation to be grounded in embodied experience. Candy and Dunagan champion this type of speculation, asserting there is a need to, "*bridge the experiential gulf between inherently abstract notions of possible futures, and life as it is apprehended, felt, embedded and embodied in the present and on the ground*" [7:137]. While Candy and Dunagan use a guided activity to co-create an experiential scenario, Elsdon et al. have used a slightly different technique to *enact* speculations. Speculative enactments are crafted to, "*intervene in familiar routines and experiences*" [15:5393] in ways that open the door for participants to feel a comfortable and meaningful connection to the content of the speculation. The High Water Pants follow suit of embodied speculation by creating an experience which relies on felt and embodied experiences in place and histories of practice in Seattle to ground the speculation, and the consequent future scenarios.

Tangible, Wearable HCI for Cyclists

Finally, the High Water Pants are part of a tradition of in-situ and embodied, tangible technologies for cycling. In the case of way-finding, the Tacticycle and the Vibrobelt both use vibration as a tool for navigation [40,48]. Safety-oriented cycling designs include a series of light-up wearable displays that communicate cyclist's intentions in conjunction with their gestures and light-up displays which can enhance clear communication between cyclists and cars in urban settings [8,9,19]. Other designs use the senses to enhance bike maintenance relationships, for instance in Rep(AIR) smell is an interface for alerting a cyclist of bike maintenance issues on a long, solo bike packing trip [25]. These examples use tactile, gestural and sensory interfaces to assist cyclists where screen-based interactions on bikes can be difficult. However, none of these examples engage with how cyclists are imbricated in their local ecosystems or climate change.

Instead, most wearable and tactile designs for cyclists focus on safety, bike maintenance and navigation.

To summarize, the High Water Pants follow the recent focus in SHCI on post-anthropocentric approaches to sustainability. They use embodied and material speculation approaches while also aligning with a history of tactile and wearable technologies for cyclists. Through these methods and ideological approaches to design, the High Water Pants are a material artifact which creates an opportunity for everyday cyclists to experience sea level rise data and author personal speculation about climate change based on their history of practice in tangible and embodied ways.

UNDERSTANDING CYCLISTS' RELATION TO CLIMATE CHANGE

In order to begin to understand how everyday cycling might intersect with climate change, we needed to understand how cyclists and their practices already intersected with climate and the weather. Understanding existing intersections helped us to imagine what kind of speculative artifact could meaningfully fit into cyclists' existing everyday practices. In this section, we explain how we used first-person experience prototypes, semi-structured interviews, and probes to learn about cyclists' existing practices and how those could be leveraged to tangibly understand climate change. As we underwent these phases of RtD, it became apparent that designing a speculative artifact about climate change for cyclists was reciprocally influenced by the ways that cyclists notice climate and nature. Therefore the research done in concert with cyclists impacted the types of technologies we felt compelled to design.

Broad, rapid first-person experience prototypes

Part of our research was conducted through a first-person approach [11,21,25,34] using a series of rapid experience prototypes run by Biggs. Biggs conducted four first-person experiments over the course of six weeks using sketches to ideate, then building low-fidelity experience prototypes to use, and finally reflecting on experiences and insights from those explorations through writing short accounts of them, all along discussing and sharing with Desjardins. These experience prototypes probed connections between cyclists' relationships to their gear, their environment (natural and built) and the elements. Through these experiments we became committed to making a functioning artifact which would offer qualities of material speculations [50] and embodied speculations [7,15], where the experience of using something designed to ask questions brings those questions to life in unexpected ways. We also became interested in cycling gear as an artifact which already mediates between the cyclist and climate, and it was only a small push to make it more actively stimulate reflection on cyclists' intersections with climate change.

Two examples of these explorations are the *Assemblage Shooter* and *In the Elements* (Fig. 2). The *Assemblage Shooter* was an experiment which explored the assemblages cyclists are enmeshed in. Biggs created a layered animated

GIF with a series of photos taken during a bike ride in the background and a subjective mind map showing an imagined network of objects (including Cheetos, asphalt, etc.) related to cycling in the foreground. The goal was to use the objective record of the ride taken by photographs with a subjective mind map to heighten awareness of and reveal more-than-human cycling assemblages. The goal of *In the Elements* was to reflect on intersections of cyclists with the elements by cutting a heart shaped hole in cycling shorts and going on a ride to try to achieve a heart-shaped tan. This little heart added a layer of reflection to how the sun is a part of cycling and highlighted the tension between the risk and joy involved in frequent, prolonged exposure to the sun. Ultimately Biggs' first-person explorations helped us narrow our research question to ask how bike gear could help everyday cyclists tangibly understand their intersections with climate change which also emphasize assemblages cyclists are enmeshed in.



Figure 2: First person experience prototypes: *Assemblage Shooter* (left) *In the Elements* (right)

Semi-Structured Interviews

After refining our research question through first-person explorations, we sought to understand how everyday cyclists understood climate, weather and climate change in order to hopefully use these insights to create a meaningful speculative artifact for understanding cyclist's intersections with climate change. To accomplish this, we conducted semi-structured interviews with six Seattle bike commuters. We recruited from personal networks via social media as well as local cycling communities. Our semi-structured interviews sought to investigate cyclists' practices in relation to the weather and their attitudes about climate change. Participants rode their bike an average of 4-7 days a week year-round, ranged from age 29-63, had ridden between 2 and 20 years and had between 1.5 and 15 mile commutes one-way. The participants' professions were a school administrator, a building engineer, a bike shop owner, a user experience designer, a bike shop program manager and a nutritionist.

We used these interviews to ask cyclists about their history of cycling and details about their cycling practices, specifically about they relate to understanding Seattle's climate and weather. We followed by asking them open-ended questions about their feelings about climate change

and if they had seen any trends in their cycling practices that they attributed to climate change.

Speculative Probe

Because we wanted this design artifact to be speculative and future-looking, we created a cultural probe kit [16] to help us move from the ‘as is’ understanding of everyday cyclists we gained through semi-structured interviews into a more speculative, future-oriented space which took into account input from participants (Fig. 3). This probe wasn’t perfectly aligned with Gaver’s vision of a cultural probe in that some activities sought descriptive information, but other activities left more room for open interpretations, creativity and the unexpected.



Figure 3. Speculative Cultural Probe Kit: *My Route By Season* (back) *Strange Sensor* (center) *Gabbing Gear* (front/left)

We recruited five participants to complete the probe, two of whom had been a part of the semi-structured interview. These participants ranged from age 23-45 and rode different types of bikes (one rode a fixed gear bike) for different reasons—three just commuted but two also rode for work, either as a group ride leader or a bike messenger. Again, they were required to ride an average of 4+ days a week for at least the last 2 years. Their professions were a spin class instructor/bike shop owner, a data visualization designer, a college student/bike courier, a user experience designer, and an administrator at a non-profit.

The probe had three different activities, a map, a booklet and imaginary sensors. The mapping activity, called *My Route by Season* used guided sketching over a map to offered detailed and Seattle-cycling-specific interactions between geography, ecology, seasons and weather to emerge. The booklet, called *Gabbing Gear*, was inspired by design workbooks [10,17] and allowed bike-related clothing and gear to speak in the first person about their understanding of weather and concerns about climate change. This activity allowed relationships about weather and speculations about climate change to emerge while also giving a non-human actor a voice (albeit the human was imagining their voice), building empathy for more-than-human things in the cycling practice. Finally, *Strange Sensors* was a set of imaginary sensors which prompted cyclists to imagine what a set of sensors

which used ‘alien’, and therefore limitless, technologies (inspired by ‘magic machines’ [1,6]). By asking participants to describe and sketch what these strange sensors could tell them about climate change and asking how they would fit into their cycling practices, our goal was to build a speculative landscape of imaginary sensors that also revealed what cyclists were curious to know about climate change. These probes were deployed with each participant for about a week and then collected, analyzed and thematically coded.

Initial Findings

The results of the first-person experiments, alongside the interviews and probes with the Seattle cycling community, show cyclists have a deep imbrication with and understanding of weather as well as genuine concerns about how climate change will impact their cycling practices. Cyclists bring unique insights to SHCI in their deep daily connection to nature and the elements which shifts the types of intersections they will have with climate change but also produces different types of knowledge and ways of being in the world. Furthermore, cyclists’ relation to climate change and their city’s topography and micro-climates provoke new ways of thinking creatively about how to feel, see, and engage with climate change. These findings were central to guiding the ideation and conceptual refinement of the High Water Pants.

Cyclists have rich sensorial and embodied understanding of Seattle’s climate

Cyclists use trail conditions, smell, and feeling/touch to track the seasons. During different seasons, roads and trail conditions change—a trail might be sprinkled with pollen or cherry blossoms in the spring, covered in black ice and fallen leaves in early winter and visited by rabbits in the summer. Cyclists also experience seasons through smells such as lilacs in spring or the “moldy fresh” air of fall (Darla (all names used are pseudonyms to protect the anonymity of participants)). Feeling also factors in to understanding the seasons, for example, Darla describes fall air as, “*less humidified and more crisp*,” and Alton says he knows it’s winter when his metal handle bars “*get [extremely] cold*.”

Being ‘one with it all’ and more-than-human actors

While cycling is an every-day activity, at times mundane, participants reported occasionally being struck by moments of wonder and transcendence. Describing being caught in very heavy rain, participant Darla recounts feeling so drenched she felt, “*one with it all*.” In another anecdote, Micha explains a surreal experience when a flying-v of ducks included him in their ‘v’ one morning on the Burke-Gillman trail. He comically recalled thinking, “*Am I a duck!?*” In addition, cyclists noted a great deal of plant and animal life they interact with on their rides like geese, rabbits, crows and gnats, as well as blooming flowers, leaves, and smells of lilac, jasmine and fennel, to name a few. Cyclists also care about the health of local ecologies: in his *Strange Sensor* response, Jack wanted to sense the health of nearby plants.

Climate change is deeply distressing but difficult to perceive at the scale of everyday life

As mentioned in the introduction, climate change is happening at a scale beyond immediate perception—a realization that came up first in the semi-structured interviews with everyday cyclists. While most interviewed cyclists reported deep sadness about the concept of climate change, they had a hard time pinpointing tangible evidence of climate change in their everyday commute. For example, when asked how they feel about climate change, participants responded, “*I believe in it . . . because science*” (Brad) or, “*It makes me extremely sad*” (Annie). However, when asked if they have noticed trends in local weather that they would attribute to climate change, people responded with uncertainty, often citing difficulty locating it spatially or temporally. Micha, who had been riding for the past 15 years was hesitant to point to trends related to climate change: “*I’d like to say. I think so, yeah. Nothing so drastic that I can put my finger on it.*”

Cyclists’ hunches about climate change impacts are ambivalent

Interestingly, when prompted to speculate about their current and future intersections with climate change based on their experiences riding a bike locally, participants eventually admitted to having hunches about weather trends and climate change, but, while their feelings about climate change at a global/abstract scale often described catastrophe and despair, their local/personal reflections weren’t necessarily negative! It was ambivalent whether hotter summers would be good or bad (some cyclists reported disliking heat, others seemed to think they would ride more) and some thought more variable weather made for beautiful and interesting riding conditions like double rainbows (Darla). All of this is to say that local, personal narratives about experiences of climate change are more ambiguous and complex than ‘global’ or large-scale narratives passed through media.

Cyclists fear climate change will add complexity to their gear rituals and routines

Cyclists acknowledge changes in the seasons by changes in what they pack and what they wear. When confronted with impending climate change, we started to see anxiety in some of the cyclists’ attitudes towards gear. Especially in the *Gabbing Gear* probe, it became clear that cyclists were concerned with increased complexity of riding in weather that might become hotter or more extreme with harder precipitation. Micha’s *Gabbing Gear* demonstrates this. He took a picture of a collection of layers he uses to ride in variable weather—when the gear considers climate change, his pile of gear says back to him, “*carrying more and more stuff may just make you quit altogether*” showing how frustrating and complex gear can already be and insinuating climate change will make it worse. Other participants mentioned their gear becoming obsolete, like when Dan discusses how a lot of his gear will be too warm for hotter summer days and not able to withstand harder rain, describing a jacket as, “*too thin for increase/heavier rain*”

and shoes as, “*too hot for warmer summers.*” Cyclists also expressed concern about their gear degrading in *Gabbing Gear* and interest in tracking what would degrade it in *Strange Sensors*. In his *Gabbing Gear* reflection, Jack worried if it got too hot, the plastic on his helmet might melt.

Cyclists want to sense short term aspects of climate change

Finally, in the *Strange Sensors* exercise specifically, it became clear that many cyclists wanted to sense information about climate change that was more about temperature and air quality, with five of the sketches dealing with air quality and three with temperature. Cyclists were also curious about wind and rain with three sketches devoted to each of these issues as well. There were a few examples of sensors sensing systemic and non-human intersections. One person wanted to track how shifting rain composition degraded their bike components, and another wanted to know where air particulate matter came from globally. There were no real future-reaching sensors, most were situated in the present tense.

Design inspiration from Findings

Using these findings, we created high-level opportunities that could guide design such as: weird gear for wild weather—like an anxious coat that shifts shape for variable weather, symbolic decay and material histories; or a coat made of material that tracks rain acidity or salinity, and post-anthropocentric sensors; or sensors that expose human-non-human connections via sensing air quality or over-heating. These were jumping off points for reflection and ideation which we discuss in the following section.

HIGH WATER PANTS CONCEPT AND CONSTRUCTION

This section is an account of generating the High Water Pants concept, the process of fabricating the pants, and then insights from a small study deploying the pants with everyday cyclists.

Design Principles

Through the first part of this RtD process, several tenets and design outcomes became important and we noted them as principles for design. First, we aimed to resist design directions that sought to ‘solve’ climate change or change the behavior of research participants. Second, we wanted to validate and integrate the practices of Seattle’s everyday cyclists. Everyday cyclists’ history of cycling ultimately became the bridge to creating the High Water Pants which leveraged cyclists’ embodied experience of weather and seasons into a way to support embodied speculation about sea level rise. Finally, we wanted to design for noticing and awareness as a way to allow nuanced, open ended narratives about intersections of cycling and sea level rise to form from participant’s histories of situated practice as Seattle cyclists. The High Water Pants embody these tenets.

Ideation

After a generative process of sketching a wide range of ideas, we became interested in creative a mechatronic garment that allowed cyclists to experience climate change data in situ. After playing with ideas related to both cyclists’ anxiety

about more extreme weather (an anxious, shape shifting raincoat) and hotter summers (a jersey that constricted ribcages to represent raising temperatures), we ultimately decided to move forward with the High Water Pants because the associated data sets created a clearer feeling, the speculative setting was a longer-term scenario, and the pants were less cruel and uncomfortable of a sensation for the rider.

The final design concept for the High Water Pants started as a series of sketches. We created a template to sketch on top of which included a person riding a bike and standing from multiple angles and analyzed types of movements and mechanics possible. In order to better understand movement of a cyclists and how their clothing might relate to that, we created a series of GIFs to illustrate the movement of the highwater pants on the cyclists as they rode.

Concept

The High Water Pants are named after the colloquial term for pants that end above the ankle, jokingly associated with a coming flood—a play on how the concept is tied to data about sea level rise in the Puget Sound [32]. We were motivated to use sea level rise data because it is a longer-term and slower impact of climate change that relates directly to Seattle's unique geography and hydrology as a city situated besides the Puget Sound.

The High Water Pants work by the pant legs dynamically shortening in correspondence with areas in Seattle that will be acutely impacted by sea level rise in the future. This movement signals to the rider they are in a location that will be affected by sea level rise in 30 to 80 years into the future. Although Seattle is not at risk of completely and dramatically disappearing under water, we are projected to experience more flooding caused by storm surges and high tides due to higher water tables. The High Water Pants use NOAA sea level viewer maps [35] as a reference for creating geofences. We used the mapping of future sea level rise as a data set for the pants because it was relatively binary—a cyclist would either be roughly inside or outside an area of impact. The either/or nature of the data and created a simple 'up' or 'down' movement with the pants. The pants actuate within these geofenced impact areas through calculating location via a GPS module embedded in the pants, which is connected to a microcontroller as a soft circuit. The GPS' latitude and longitude readings are passed through a polygon detection algorithm run through to a microcontroller. In order to give the cyclist wearing the High Water Pants more opportunity for reflection and to account for the ambiguity of how climate change will impact coastal areas of Seattle, we padded the geofences slightly (fig. 4). These geofences are not only places where sea level will impact Seattle, but also represent popular cycling destinations mentioned in the *My Route by Season* probe exercise.

Somatic Experience

Mechanically, the sensation on the leg was developed to be simple and distinct, yet comfortable. This was important because a lower leg isn't able to feel at a fine grain of detail



Figure 4. Map showing areas in Seattle that will be impacted by sea level rise (yellow) and geofences (pink).

so meaning had to be made through clear movements. In the case of a long ride within a geofence, a more acute sensation (vibration or knocking against the cyclist with the arm of a servo motor) might get annoying and hinder reflection or enjoyment of the bike ride. The raising and lowering pant leg is more innocuous and fades in and out of the cyclists' direct attention, calling attention to borders or thresholds, while maintaining the ability into fade to a background sensation.

The subtlety of the feeling was important so that cyclists would have space to mesh new data with their history of cycling to understand climate change. While the raising of the pants helps cyclists discover geographic areas of impact, the static state gives them opportunities to reflect as they ride about futures with sea level rise. The garment has the potential to fill a gap in cyclists' understanding of intersections of sea level rise and cycling.

Crafting the Pants

Building these pants required synthesizing systems of feeling (the leg) while in motion (the legs turning the pedals of the bike) via designing soft-mechanical interfaces and choosing information structures that would yield meaningful tactile results. The prototyping process reflects that: we shifted between iterations that were wholistic and messy and then moved into targeted explorations that focused on the lower leg for ease of attachment and motion. Once the mechanism for raising the pant leg was in place, we refined the code for creating/detecting geofences using live GPS with assistance of software developers and new media artists. Finally, we solidified materials and formalized the pants via rapid testing and prototyping. Two pairs of High Water Pants were created. One pair was all yellow, which was used for two museum exhibitions, and the other pair used the same pattern but was tan and black—this pair was used for a deployment study.

HIGH WATER PANTS IN USE

After crafting the High Water Pants, the final phase of our R&D process was deploying the pants with everyday cyclists to observe how embodied interactions with sea level rise data could spur unique and situated speculation about their futures

with sea level rise. Deploying the High Water Pants with cyclists resulted in participant speculations around possible futures, responses to the experience of finding boundaries, and reflections on the new awareness about climate change.

We deployed the pants with three cyclists, Darla, Mort, and Patricia age 29, 35 and 38, who have ridden three or more times a week for between five and eleven years. The participants were two designers, both new to the study, and one bike shop owner (Darla) who was also a part of every phase of our research.

To start, we met with the participant and had them put the pants on and gave them an overview of the concept. We explained the basic mechanics of the pants and told participants roughly where to ride since the pants currently only support one geofence at a time. We explained that the pants represented sea level rise predicted by NOAA but that the impacts of sea level rise were predictions, not guarantees. We also explained sea level rise will be affected by Seattle's unique geography, hydrology and tides. We then told the cyclists to ride around for as long as they found the experience interesting. When they returned, we conducted an exit interview to ask about general impressions, how the garment felt, any speculations they had about what that area might be like when sea levels are higher, and how their history of everyday cycling helped them formulate those speculations

Findings from the study

One of the first things we noticed was the anecdotal reflection cyclists had on impacts of sea level rise which related to memories they had as cyclists in that area or the specific ecology of the space they were riding in. In one example, Patricia told a story about how during her first few months of living in Seattle, she was having a bad day and decided to go on a bike ride to Elliot Bay. There was an event being hosted by the Seattle Art Museum and the park was so beautiful that the ride turned her feelings about Seattle into excitement and positivity. However, in our interview, she noted that sea level rise might erase public parks, *"it's such a nice open space and there's so many people utilizing it . . . but then it goes straight from park to just straight up buildings . . . I think it'd be a totally different experience living here without that access [to the waterfront] because otherwise it's like buildings [and then] water."* She realized the placement of this park by Puget Sound and the immediate rise of land/buildings directly to the east might cause the park to become less useable, reducing public/shared land. In another example, Mort reflected on how if there was chronic flooding and inundation, salt water plants might become more common, imagining the following future ecology: *"all of a sudden you get these different like kind of yellowy grasses that you usually see in estuaries . . . maybe you see like the cattails poking up different birds and that you know, suddenly the soundscape is all different."*

In addition, both Patricia and Mort remarked on the feeling of the pants, stating it was subtle, and unlike anything they

had felt before. Both mentioned how it was unlike typical, tech-type haptic feedback. Patricia remarked, *"My phone vibrates, my watch vibrates. Um, but that was different. It was like something moving . . . I can't think of anything else that moves like that. It's very unique feeling."* Similarly Mort mentioned, *"it wasn't, you know, a device beeping at me and saying like, you know, 'this is the area.' I was just feeling it, sensing it"*. The feeling of the pants was not like a feeling traditionally associated with technology and was related to the garment and the concept. The feeling was easier to feel in the 'up' position: Mort mentioned when the pants were in the up position he could feel more wind on his legs and pressure from the mechanism of the outside of his calf. Patricia and Darla also mentioned feeling the mechanism against their legs while riding.

All three participants mentioned the feeling of discovering boundaries. Patricia said it was fun and she searched for the boundaries on purpose. Darla was curious when the pants would raise based on her history of riding through Elliot Bay Park—she wondered if recent detours to the bike path would impact when they would activate. Mort also mentioned riding specifically to find the boundaries and experience them. Finally, Patricia mentioned she noticed the pants oscillating between up and down at geofence boundaries, creating a kind of anticipatory sensation in a liminal zone.

The participants also mentioned an increased awareness of the issue and an obvious focus on climate change impacts they would have never had been exposed to without the pants and the experience. Mort mentioned, sea level rise, *"became slightly more real,"* and that the High Water Pants offered him a way to notice and be more aware. Patricia mentioned she was much more aware of the issue wearing the pants. While we learned a lot from this small group of participants, future work will include a larger group of participants who have longer engagements with the pants.

DISCUSSION

Through the act of making a speculative wearable provocation for everyday cyclists to tangibly understand climate change, we engaged with climate change and cyclists on multiple levels. As a reminder, these pants weren't trying to persuade cyclists to change their behaviors to be more sustainable or directly impact climate change by reducing CO₂ emissions. Instead, our approach worked by bringing attention to and opening a space for noticing potential future impacts of climate change. This new opening responds to calls in SHCI for an attunement to climate change as a prerequisite for sustainability. In the following discussion we explore insights from making the High Water Pants. They helped us in addressing the temporality of climate change by creating speculative frameworks that 'bend time', we explored ways that research methods can strive to embrace non-human actors and how definitions of sustainability in HCI are shifting to more radical explorations where technology can mediate empathy not only for future selves but future selves-in-ecology.

‘Time Bending’ Wearables to Build Comparisons

A major through-line in this project is the acknowledgment of how difficult it is to perceive climate change at the scale of everyday life. To revisit concepts from the introduction, climate change is what Timothy Morton calls a hyperobject [33], which operates at a radically different scale than people are used to perceiving. For this reason, we argue that climate change will remain intangible unless its generational scale is ‘bent’ to a scale that humans can feel, or at least, imagine feeling. We accomplished this bending through the ‘present/future’ paradigm, where future data can be felt in the present. The present/future isn’t really a place in time, but rather the bending of two places on a timeline to touch. The present/future echoes how climate scientists use comparison to imagine climate change—for example, the summer of 2015 in Seattle, which maps to the expected temperatures of climate change some tens of years in the future, is often cited by climate scientists as a ‘dress rehearsal’ for what the future will feel like as global temperatures increase. Bending is a way of comparing—in order to *feel* climate change, one must have something to compare against so that change isn’t lost in the natural oscillation of weather patterns and the slow, incremental rate of change which makes the new seem normal.

Although the present/future lay at the heart of this speculative approach, it relied on having a localized history of a cycling practice. The way cyclists understood climate, which was a type of sensorial, embodied and gradually accrued knowledge built through daily exposure to the elements, allowed them to speculate about their futures with sea level rise through experiencing it in the present. As cyclists use the High Water Pants, we saw, as with Patricia in the deployment, that their memories and history of cycling inform—or fill out—their speculations about the future of climate change. In addition, the unique speed of riding a bike allows someone to cover a considerable distance and explore large areas of Seattle in a day or an afternoon, making them capable of drawing conclusions about both granular details about sea level rise in certain locations, as well as larger-scale impacts. While, as Timothy Morton states, “*any “local manifestation” of a hyperobject is not directly the hyperobject*” [33:1], our research shows it is possible to use local points of reference to speculate about the hyperobject of climate change. The High Water Pants’ present/future approach speculatively grounds climate change in everyday phenomenology, taking climate change from abstraction to something more concrete.

The tactility of the in-ride experience was also important to crafting the present/future speculation. Although the feeling developed through the High Water Pants isn’t an exact replication of what the future will feel like, the feeling is an intimation of what is to come, formless, waiting to be given form by the imagination of an everyday cyclist, one with a history of practice, riding through specific, familiar geographic spaces. Maxine Sheets Johnston argues in *The Primacy of Movement*, that movement forms the basis of

language [44], and knowledge which is embodied, personal, and somatic offers potential for creating new, memorable, nodes of insight about climate change which function differently than reading about it or looking at models or graphs. But ultimately, the importance of tactility of the present/future paradigm is that instead of a creative action, it offers a creative *moment*. While other speculative methods ask one to imagine abstractly, or enact or build potential futures, the High Water Pants ask participants to *be with* a possible future in real time, which leaves speculation open-ended, rooted in a personal experience and free to be authored and evolve over time.

Mediating human-non-human intersections and including non-human voices

This research was influenced by post-anthropocentric and new materialist writing such as Anna Tsing [49], Donna Haraway [20], Jane Bennett [4] and Liu et al.’s paper on collaborative survival [28]. These influences reinforced an intent to have a more-than-human focus in this project which permeated our research methods. This began during first-person explorations like *Assemblage Shooter* where we observed cycling practices as assemblages including things from the asphalt of roads to the calories from Cheetos. Again, in *In the Elements* we explored ways that garments could comment on human non-human intersections like that of skin and the sun. In the semi-structured interviews, we were pleasantly surprised to find an unprovoked language emerge around being ‘one with it all’. Some participants described themselves having transcendent experiences where their human boundaries were permeated or transformed by experiences they had while riding bikes, such as becoming part of a ducks’ ‘v’ or a torrential downpour. *Gabbing Gear* sought to give cyclists’ gear a voice which ultimately inspired the direction the High Water Pants and while guiding *My Route by Season* we asked targeted questions about relationships between cyclists, plants and animals they encounter seasonally.

The High Water Pants hold a dialogue with the cyclists riding in them through their movements which communicate climate change projections. The fact that the High Water Pants actuate based on data that they make tangible, independent of being ‘useful’ to or serving a rider’s needs, put them in dialogue with the rider. This dialogue model contrasts other more hierarchical models for human-computer interactions where users initiate interactions, for example. In this way, the High Water Pants form a horizontal relationship with the cyclists, as the pants have their own ‘language’, or way of communicating, that speaks geographically and temporally. While the pants *are* a designed artifact—the data used was modeled by climate scientists, the interaction was envisioned by design researchers, and the rider has the ability to seek out the boundaries where the pants actuate—in use, the experience of all of these elements as a coherent whole give the pants a surprisingly lively quality. There is a duality to the voice of the pants as well, for they are speaking literally and

speculatively. They speak literally about geographic locations but they are also a kind of oracle, or translator, speaking for/from an ecology-to-be, which will be impacted by sea level rise. The sentiments from earlier research methods, of exploring vibrant *assemblages* (as used by Jane Bennett [4]), intersections between bodies and elements, and sentiments of being ‘one with it all’ are synthesized in this experience, while the artifact of the pants pushes the assemblages we are a part of into a present/future duality. These concepts build on each other to engage in ways of re-framing and decentering humans in interaction designs, as well as offering methods for technological mediation that enlarge a cyclist’s focus to larger ecologies and longer time-scales.

New ways of framing Sustainability in HCI

The High Water Pants respond to recent calls in SHCI to refocus the lens through which we view ‘sustainability’ from earlier critiques of production and consumption [5,37], towards more urgent, post-anthropocentric framings and adaptive and collaborative methods for approaching sustainability. Our research uncovered how cyclists’ practices are predisposed to seeing climate and climate change through post-anthropocentric, tangible, sensorial, and embodied knowledge. They inspired us with post-anthropocentric, anecdotal reflections on becoming ‘one with it all’ in heavy rain or, briefly, becoming a duck. We were also inspired by how they expressed *ambiguous* outcomes of climate change, imagining it being at times beautiful and other times stressful, a perspective rarely explored in SHCI. We leveraged this unique worldview to explore intersections between climate change and everyday cyclists in a tangible and sensorial way, which left room for non-humans, appreciation of the sublime in nature, and ambiguous outcomes.

The combination of the tangible interface which enables a ‘time bending’ comparison and the overarching focus on attempting to include non-humans throughout the research process offers new models for thinking about how climate change must be framed and how technologies can help frame it. We used the traditional tools of HCI: micro-controllers, interfaces, data sets, and used them to create tools for reflection and imagination. While many narratives around climate change read as catastrophic and overwhelming, the sentiment that cycling is lovely, even in torrential downpours (perhaps encountering the sublime) can complicate narratives of climate change. For example, as participants encountered future-self-in-ecology assemblages using the High Water Pants in our study, they noted loss of public land (Patricia) on the one hand, but also imagined emergent ecosystems (Mort) on the other hand. In order to imagine adaptive and co-creative paths forwards in the face of climate change, it seems beneficial to design technologies that allow people to conduct open-ended explorations that are rooted in experience and history of a place, which allow for curiosity, hope, beauty, destruction, playfulness and concern to all coexist. We believe this is a resilient approach to engaging

and understanding paths forward as we reckon with possible futures with climate change.

Design theorist Ann Light, synthesizing calls from Timothy Morton, Anna Tsing and Donna Haraway to seek a model of kinship with more-than-human actors, suggests that designers should strive to, “*design to unseat humans from the center of the universe and support a more equitable gaze*” [27:728]. Moreover, Donna Haraway has recently argued we must, ‘stay with the trouble’ [20], a statement which encompasses the argument that approaches to sustainability require acknowledgement of climate change and radical reorientation through post-anthropocentric frameworks to survive. Following this charge, the High Water Pants not only stay with the trouble, but bring the ‘trouble’ of climate change and sea level rise that is beyond our perception into a scale that can be grappled with and speculated over within the context of everyday cycling. These pants also seek relationships with non-living agents, seeking connection to bodies of water, parks, and geographic locations—expanding the terrain of non-humans to the non-living, reflecting arguments by Jane Bennett that matter doesn’t have to be living to be vibrant [4].

CONCLUSION

This paper presented an account of the RtD process of creating the High Water Pants as well as a discussion of their implications. At their core, the High Water Pants are an object of inquiry (or the opportunity to continue this line of questioning) and their fabrication created an opening for continued research. The point of these pants isn’t to solve the problem of climate change or persuade people to change their behavior, but to explore how climate change can be brought to the tangible scale of everyday life through the specific instance of climate change’s intersection with everyday cyclists. The pants extend a cyclist’s ability to notice and be aware of those intersections through ‘bending time’, overlaying future data over present experiences while also emphasizing cyclists’ connections to larger assemblages which they are a part of. Through combining and engaging in tangible technologies for cyclists and speculation, the High Water Pants enable local, personal narratives about climate change to emerge, offering cyclists a tactile interface through which they can notice and reflect on longer-term, future impacts of sea level rise that are curious and engage the cyclist in reflection on their imbrications with their surrounding ecology.

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REFERENCES

- [1] Kristina Andersen. 2013. Making Magic Machines. In *10th European Academy of Design Conference - Crafting the Future*, Gothenburg, Sweden, 1–11. <https://doi.org/10.2307/j.ctvg8p3md.12>
- [2] James Auger. 2013. Speculative design: Crafting the speculation. *Digital Creativity* 24, 1: 11–35. <https://doi.org/10.1080/14626268.2013.767276>
- [3] Annette Becker, Stefanie Lampe, Lessano Negussie, and Peter Cachola Schmal. 2018. *Ride a Bike! : Reclaim the City*. Birkhäuser, Basel, Switzerland.
- [4] Jane Bennet. 2009. *Vibrant matter: A political ecology of things*. Duke University Press.
- [5] Eli Blevis. 2007. Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*, 503–512. <https://doi.org/10.1145/1240624.1240705>
- [6] Mark Blythe, Kristina Andersen, Rachel Clarke, and Peter Wright. 2016. Anti-solutionist strategies: Seriously silly design fiction. In *Proceedings of the 2016 CHI Conference (CHI '16)*, 4968–4978. <https://doi.org/10.1145/2858036.2858482>
- [7] Stuart Candy and Jake Dunagan. 2017. Designing an experiential scenario: The People Who Vanished. *Futures* 86: 136–153. <https://doi.org/10.1016/j.futures.2016.05.006>
- [8] Alexandru Dancu, Zlatko Franjic, and Morten Fjeld. 2014. Smart flashlight: map navigation using a bike-mounted projector. *Proceedings of the 2014 SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*: 3627–3630. <https://doi.org/10.1145/2556288.2557289>
- [9] Alexandru Dancu, Velko Vechev, Advaye Ayça Ünlüer, Simon Nilson, Oscar Nygren, Simon Eliasson, Jean-Elie Elie Barjonet, Joe Marshall, and Morten Fjeld. 2015. Gesture Bike: Examining Projection Surfaces and Turn Signal Systems for Urban Cycling. *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces (ITS '15)*: 151–159. <https://doi.org/10.1145/2817721.2817748>
- [10] Audrey Desjardins, Jeremy E. Viny, Cayla Key, and Nouela Johnston. 2019. Alternative Avenues for IoT. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*: 1–13. <https://doi.org/10.1145/3290605.3300581>
- [11] Audrey Desjardins and Ron Wakkary. 2016. Living in a prototype: A reconfigured space. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*, 5274–5285. <https://doi.org/10.1145/2858036.2858261>
- [12] Kristin N. Dew and Daniela K. Rosner. 2019. Designing with waste: A situated inquiry into the material excess of making. *Proceedings of the 2019 ACM Designing Interactive Systems Conference (DIS '19)*: 1307–1319. <https://doi.org/10.1145/3322276.3322320>
- [13] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the landscape of sustainable HCI. In *Proceedings of the 28th international conference on Human factors in computing systems (CHI '10)*, 1975–1984. <https://doi.org/10.1145/1753326.1753625>
- [14] Jan Van Duppen and Bas Spierings. 2013. Retracing trajectories: The embodied experience of cycling, urban sensescape and the commute between “neighbourhood” and “city” in Utrecht, NL. *Journal of Transport Geography* 30: 234–243. <https://doi.org/10.1016/j.jtrangeo.2013.02.006>
- [15] Chris Elsdén, David Chatting, Abigail C. Durrant, Andrew Garbett, Bettina Nissen, John Vines, and David S. Kirk. 2017. On Speculative Enactments. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*: 5386–5399. <https://doi.org/10.1145/3025453.3025503>
- [16] Bill Gaver, Tony Dunne, and Elena Pacenti. 1999. Design: Cultural probes. *Interactions* 6, 1: 21–29. <https://doi.org/10.1145/291224.291235>
- [17] William Gaver. 2011. Making Spaces: How Design Workbooks Work. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*, 1551–1560. <https://doi.org/10.1145/1978942.1979169>
- [18] William Gaver. 2012. What should we expect from research through design? *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems (CHI '12)*: 937–946. <https://doi.org/10.1145/2207676.2208538>
- [19] Tobias Grosse-Puppenthal, Oskar Bechtold, Lukas Strassel, David Jakob, Andreas Braun, and Arjan Kuijper. 2015. Enhancing traffic safety with wearable low-resolution displays. *Proceedings of the 2nd international Workshop on Sensor-based Activity Recognition and Interaction (WOAR '15)*: 1–10. <https://doi.org/10.1145/2790044.2790059>
- [20] Donna J. Haraway. 2016. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press.
- [21] Kristina Höök, Baptiste Caramiaux, Cumhur Erkut, Jodi Forlizzi, Nassrin Hajinejad, Michael Haller, Caroline Hummels, Katherine Isbister, Martin Jonsson, George Khut, Lian Loke, Danielle Lottridge, Patrizia Marti, Edward Melcer, Florian Müller,

- Marianne Petersen, Thecla Schiphorst, Elena Segura, Anna Ståhl, Dag Svanæs, Jakob Tholander, and Helena Tobiasson. 2018. Embracing First-Person Perspectives in Soma-Based Design. *Informatics* 5, 1: 8. <https://doi.org/10.3390/informatics5010008>
- [22] Parkin, John. 2012. *Cycling and sustainability*. Emerald Group Publishing Limited.
- [23] Phil Jones. 2005. Performing the city: A body and a bicycle take on Birmingham, UK. *Social and Cultural Geography* 6, 6: 813–830. <https://doi.org/10.1080/14649360500353046>
- [24] Li Jönsson and Tau Ulv Lenskjold. 2015. Stakes at the edge of participation: where words and things are the entirely serious title of a problem. In *Nordes 6.1*, 1–9. Retrieved from <http://www.nordes.org/opj/index.php/n13/article/view/371>
- [25] Cayla Key and Audrey Desjardins. 2019. REP (AIR): An Olfactory Interface For Bike Maintenance and Care. In *Proceedings of the 4th Biennial Research Through Design Conference*. <https://doi.org/https://doi.org/10.6084/m9.figshare.7855769.v3>
- [26] Bran Knowles, Oliver Bates, and Hakansson Maria. 2018. This Changes Sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '18)*, 1–12. <https://doi.org/10.1145/3173574.3174045>
- [27] Ann Light, Irina Shklovski, and Alison Powell. 2017. Design for Existential Crisis. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '17)*: 722–734. <https://doi.org/10.1145/3027063.3052760>
- [28] Jen Liu, Daragh Byrne, and Laura Devendorf. 2018. Design for Collaborative Survival. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*, 1–13. <https://doi.org/10.1145/3173574.3173614>
- [29] Szu Yu Liu, Shaowen Bardzell, and Jeffrey Bardzell. 2019. Symbiotic encounters: HCI and sustainable agriculture. In *Proceedings of the 2019 CHI Conference (CHI '19)*, 1–13. <https://doi.org/10.1145/3290605.3300547>
- [30] G.S.; J.H. Casola; H.A. Morgan; R.L. Strauch; B. Jones; B. Curry; T.M. Busch Isaksen; L. Whitely Binder; M.B. Krosby; and A.K. Snover Mauger. 2015. *Adapting to change*. <https://doi.org/10.1038/nphoton.2010.302>
- [31] Guillaume Mauger, Joseph Casola, Harriet Morgan, Ronda Strauch, Brittany Jones, Beth Curry, Tania Busch Isaksen, Lara Whitely Binder, Meade Krosby, and Amy Snover. 2015. *State of Knowledge: Climate Change in Puget Sound*. <https://doi.org/10.7915/CIG93777D>
- [32] Ian Miller, Harriet Morgan, Guillaume Mauger, Ray Weldon, David Schmidt, Mark Welch, and Eric Grossman. 2018. *Projected Sea Level Rise for Washington State - A 2018 Assessment*.
- [33] Timothy Morton. 2013. *Hyperobjects: Philosophy and Ecology After the End of the world*. U of Minnesota Press.
- [34] Carman Neustaedter and Phoebe Sengers. 2012. Autobiographical Design in HCI Research: Designing and Learning through Use-It-Yourself. *Proceedings of the 2012 Designing Interactive Systems Conference (DIS '12)*: 514–523. <https://doi.org/10.1145/2317956.2318034>
- [35] NOAA. 2019. NOAA Sea Level Rise Viewer. Retrieved from <https://coast.noaa.gov/slr/>
- [36] William Odom, Richard Banks, Abigail Durrant, David Kirk, and James Pierce. 2012. Slow technology: critical reflection and future directions. *Proceedings of the Designing Interactive Systems Conference on (DIS '12)*, October 2015: 816–817. <https://doi.org/10.1145/2317956.2318088>
- [37] William Odom, James Pierce, Erik Stolterman, and Eli Blevis. 2009. Understanding why we preserve some things and discard others in the context of interaction design. *Proceedings of the 27th International Conference on Human Factors in Computing Systems (CHI '09)*: 1053–1062. <https://doi.org/10.1145/1518701.1518862>
- [38] William Odom and Ron Wakkary. 2015. Intersecting with Unaware Objects. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition (C&C '15)*, 33–42. <https://doi.org/10.1145/2757226.2757240>
- [39] Robert Phillips and Kaylene Kau. 2019. Gaming for Active Nature Engagement Animal Diplomacy Bureau: designing games to engage and create player agency in urban nature. *The Design Journal* 22, sup1: 1587–1602. <https://doi.org/10.1080/14606925.2019.1594993>
- [40] Martin Pielot, Benjamin Poppinga, Wilko Heuten, and Susanne Boll. 2012. Tacticycle: Supporting Exploratory Bicycle Trips. *Proceedings of the 14th international conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '12)*, September: 369–378. <https://doi.org/10.1145/2371574.2371631>
- [41] James Pierce and Eric Paulos. 2014. Counterfunctional things: exploring possibilities in designing digital limitations. In *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*, 375–384.

- <https://doi.org/10.1145/2598510.2598522>
- [42] James Pierce and Eric Paulos. 2015. Making Multiple Uses of the Obscura 1C Digital Camera. In *Proceedings of the 2015 CHI Conference on Human Factors in Computing Systems (CHI '15)*, 2103–2112. <https://doi.org/10.1145/2702123.2702405>
- [43] John Pucher and Ralph Buehler. 2008. Making cycling irresistible: lessons from the Netherlands, Denmark and Germany. *Transport reviews* 28, 4: 495–528.
- [44] Maxine Sheets-Johnstone. 2011. *The primacy of movement*. John Benjamins Publishing.
- [45] Nancy Smith, Shaowen; Bardzell, and Jeffrey Bardzell. 2017. Designing for Cohabitation : Naturecultures, Hybrids, and Decentering the Human in Design. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*: 1714–1725. <https://doi.org/http://dx.doi.org/10.1145/3025453.3025948>
- [46] Justin Spinney. 2009. Cycling the city: Movement, meaning and method. *Geography Compass* 3, 2: 817–835. <https://doi.org/10.1111/j.1749-8198.2008.00211.x>
- [47] Pieter Jan Stappers and Elisa Giaccardi. 2017. Research through design. *The encyclopedia of human-computer interaction*, 2.
- [48] Haska Steltenpohl and Anders Bouwer. 2013. Vibrobelt. In *Proceedings of the 2013 International Conference on Intelligent User Interfaces (IUI '13)*, 417–426. <https://doi.org/10.1145/2449396.2449450>
- [49] Anna Lowenhaupt Tsing. 2015. *The Mushroom and the End of the World: On the possibility of life in capitalist ruins*. Princeton University Press.
- [50] Ron Wakkary, William Odom, Sabrina Hauser, Garnet Hertz, and Henry Lin. 2015. Material Speculation: Actual Artifacts for Critical Inquiry. *Aarhus Series on Human Centered Computing* 1, 1: 12. <https://doi.org/10.7146/aahcc.v1i1.21299>