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Method &
Critique *Frictions and Shifts in RTD*



REP(AIR): An Olfactory Interface For Bike Maintenance and Care

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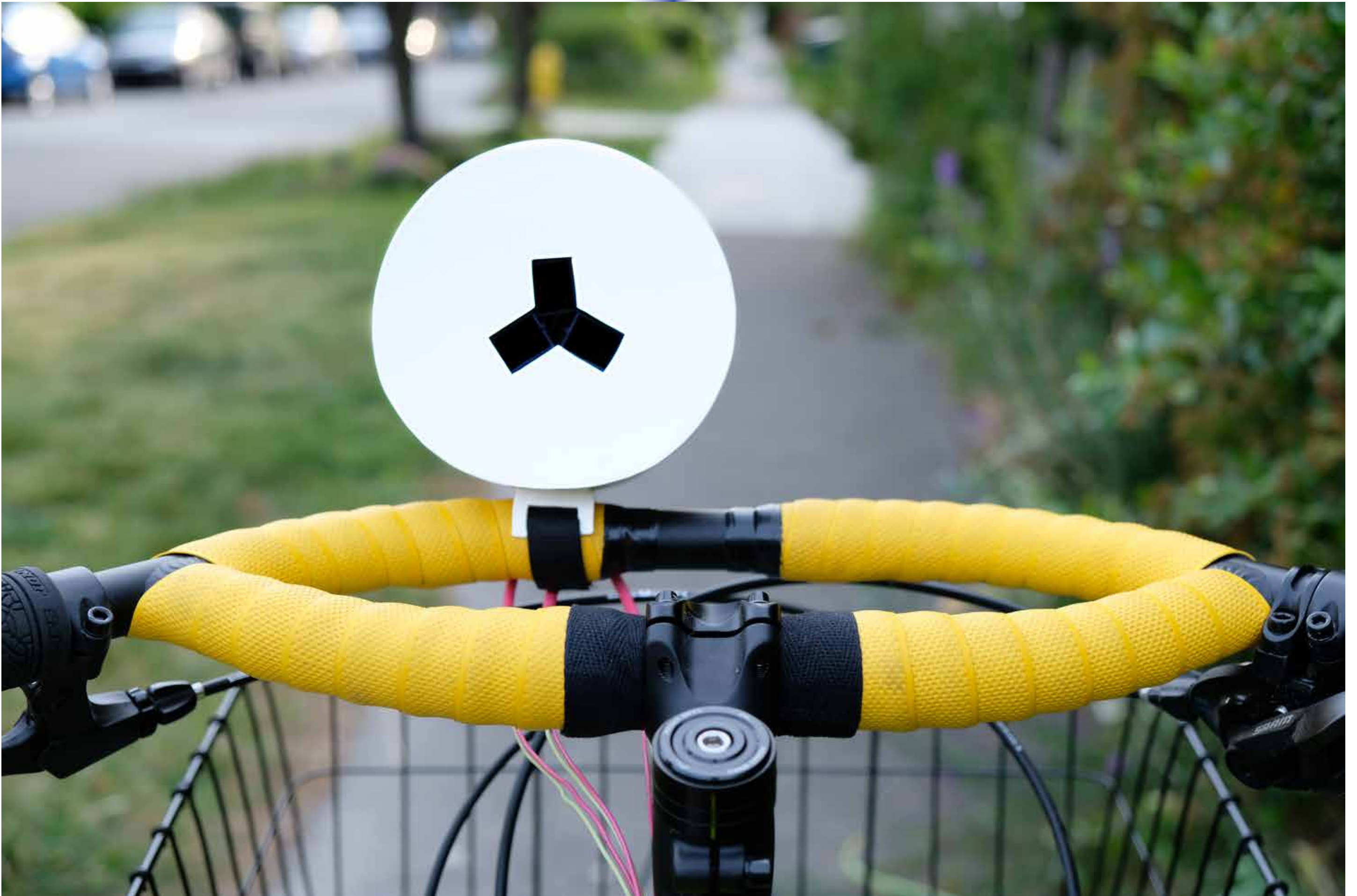
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Abstract: In this paper we present Rep(AIR), a research-through-design olfactory interface for communicating moments of wear and tear on a bicycle. Rep(AIR) was designed as a probe in an autobiographical design inquiry to uncover qualities of the relationship between humans and objects as they relate to breakage and repair. Key used Rep(AIR), along with a personal probe notebook, on a 12 day international cycling trip to reflect on and document repairs and maintenance. We share findings from our analysis which extend the discourse on repair to include moments of wear, maintenance, and care as a part of the ongoing process of everyday use; recenter functionality to the human-object team, rather than the object alone; and highlight teamwork and collaboration as a way to challenge the hierarchical human-object narrative. We conclude by noting the role of Rep(AIR) as a tool which gave the bicycle a voice—revealing the often uncommunicated experience of wear and tear on an object.

Keywords: olfactory interface; bicycle; autobiographical design; maintenance; repair; care

Method & Critique



Introduction

Wear, care, breakage, and repair are all part of the long (or short) lives of things. Design and human-computer interaction (HCI) scholars have built a strong theoretical and empirical corpus of work on repair, care and maintenance in relation to everyday objects, technological artifacts, and infrastructures. Repair has been positioned in relation to planned obsolescence and sustainability (e.g., Blevis 2007), as a practice that negotiates endurance in a sociomaterial system (e.g. Rosner and Ames 2014; Houston et al. 2016), as well as an everyday creative practice (e.g., Maestri and Wakkary 2011). In this paper, we extend this work by turning our attention to the intimate and ongoing practice of maintaining one's things. Previous works have made clear that repair should be considered a 'normal' part of our life with objects (Jackson 2014), and that repair and reuse have important implications towards sustainability and personal empowerment. In response, we designed an interface to prompt and encourage care and maintenance interventions in and around an everyday practice—that of riding a bicycle.

In this paper, we present Rep(AIR)—an impact-triggered scent diffuser mounted to the handlebars of a bicycle—and the findings of a 12 day autobiographical design inquiry. Rep(AIR) was designed to interrogate how repair, care, and maintenance might contribute to the intimate relationship between humans and objects, or in this case between Key and her bicycle. To do so, Rep(AIR) brings attention to breakage and wear by establishing a new mode of communication (through scent) between the bicycle and the rider. Feedback channels conveying damage to the frame exist inherently on a bicycle; there might be sounds, vibrations, or visual signs that damage has occurred. However, all too often these warnings are hidden in the ubiquity of repetitive and habitual haptic feedback being transmitted from the bicycle to the rider on a bumpy path, often eluding consciousness and receding to the back of the mind. Rep(AIR) counteracts this familiarity by diffusing three scents depending on the type of impact or wear the bicycle is experiencing. Our design rationale is inspired by defamiliarization where the habitual is made strange and unfamiliar (Shklovsky and Reis 1965; Bell, Blythe and Sengers 2005). This use of strangeness to challenge usual thinking opens a critical space for people to “interpret situations for themselves, it encourages them to start grappling conceptually with systems and their contexts, and thus establish deeper and more personal relations with meaning offered by those systems” (Gaver, Beaver and Benford 2003). We aimed at making the minor dings and dents on the frame a strange, delayed, and curious feedback like scent in order to provoke more thoughtful reflections.

Key used Rep(AIR) during two cycling touring trips: 6 days in Mongolia, and 6 days in Slovenia, in an autobiographical design inquiry. During those trips, she gathered data on her own experience in the form of a personal probe notebook. Data included repair or maintenance acts performed, as well as reflections on her relationship to the bicycle. Both the designing and making of Rep(AIR) and the deployment allowed us to investigate the following research question: What qualities of a human-object relationship might emerge by bringing more attention to acts of repair and maintenance?

We make two contributions in this paper. First, we describe in detail the design of Rep(AIR), an olfactory interface responding to impact. This contributes to the growing corpus of works in HCI and design in sensory interfaces by offering a fully functional prototy. Second,

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Figure 1. Rep(AIR) on a mountain pass in Mongolia.

in our analysis, we articulate three themes around elevating acts of repair, maintenance, and care and repair that we observed in the deployment of Rep(AIR).

In the remainder of this paper, we present related literature around repair, peripheral interactions, scent as interface and bicycles in HCI. We then offer details around the methodological approach (autobiographical design), design process and Rep(AIR)'s specifications, as well as the results of the 12-day deployment. We conclude with a discussion on repair as part of a longer ongoing process and on the multifaceted relationship that emerged through acts of maintenance.

Related Works

Repair in design

Design and human-computer interaction (HCI) scholars have long paid attention to repair and maintenance as an important, but often overlooked, area of interest in the life of (technological) artifacts. A small but highly evocative corpus of work offers ethnographic accounts of repair communities and repair practices. Early work by Suchman (1987) and Orr (1996) were central to bringing attention to repair practices as work that holds its own technical knowledge and social-material context. Scholars have investigated the practices of Fixer collectives in the USA, phone repair communities in Uganda and Bangladesh, repair markets in Bangladesh, artists, and hobbyists (Jackson 2014; Jackson and Kang 2014; Rosner and Ames 2014; Rosner and Turner 2015; Houston et al. 2016) to name a few. In these works, repair was found to be intertwined in the socio-material contexts we live in and to be embedded in local and global networks. Repair also represents significant forms of craft-based knowledge and is an ongoing process rather than a planned script. Importantly, Houston et al. (2016) highlight how repair is a central site where values are performed and achieved and where people's relations to objects might be elevated, leading to an empowered link with artifacts (Rosner and Ames 2014).

Repair, reuse, and appropriation are at the center of discussions around planned obsolescence and sustainability—bringing into focus responsibility and opportunities to celebrate longer artifact lifecycles. Along those lines, Tsaknaki and Fernaeus (2016) propose ways to use Wabi-Sabi as a resource for design, building on the three evocative principles of: “nothing lasts”, “nothing is finished”, and “nothing is perfect” (Tsaknaki and Fernaeus 2016).

Repair was also looked at through the lens of creativity. Maestri and Wakkary (2011) report on acts of everyday repair, where lay people are resourceful and creative in the ways they repair, reuse, and repurpose everyday objects. Jackson and Kang (2014) argue that breakdown and repair are a productive lens to extend HCI's understandings of creativity. Ikemiya and Rosner (2014) created and deployed ‘Broken Probes’ as a way to elicit “insights into how broken objects and acts of breakage may be given new life” (Ikemiya and Rosner 2014). Our work builds on this rich history in design and HCI by proposing a probe that brings attention to the wear and tear of an everyday object, the bicycle. We note that our work, similarly to Ikemiya and Rosner (2014), focuses on the moments and acts of breakage as much as the acts of repair.

Peripheral interaction

Our main objective in this paper is to investigate opportunities to bring to the foreground repair and maintenance, in the case of bicycle care. To do so, we turn to peripheral interaction as a strategy for design. Peripheral interaction, or “what we are attuned to without attending to explicitly” (Weiser and Seely Brown 1997) was initially framed as a means of seamlessly integrating technology into our everyday lives under the term calm technology. Important to interaction design, peripheral interaction can “be performed in the periphery of attention when another activity is being performed simultaneously in the center of attention” (Bakker, van den Hoven and Eggen 2015). As a result, Bakker and Niemantsverdriet (2016) urge designers to utilize the full range of what they call the interaction—attention continuum to afford flexibility to attend to interactions on a level each individual deems appropriate for the context. Bolton, Jalaliniya and Pederson (2015) also position their work on graceful interruptions to allow a choice over how and when to engage with their technology by relying on the “existing interruption management infrastructure in our brains” (Bolton, Jalaliniya and Pederson 2015).

Peripheral interaction shows promise in our case because it allowed Key to act upon the olfactory feedback as she saw fit: focusing attention directly when it was safe and appropriate, allowing the information to linger in the periphery when riding, and drifting between the two as attention resources ebbed and flowed. Our work builds on the theoretical foundations of peripheral interaction and offers a clear and novel case that exhibits how olfactory feedback in the context of an everyday practice can provide meaningful peripheral awareness.

Scent as interface

Olfactory perception stands apart from other sensory systems in the way it is routed in the brain. Rather than pass through the thalamus en route to the cortex, olfactory stimuli is “relayed directly to the limbic system, a brain region typically associated with memory and emotional processes. This provides olfaction with a unique and potent power to influence mood, acquisition of new information, and use of information in many different contexts” (Sullivan et al. 2015). Furthermore, the emotional implications of acquiring knowledge through olfactory encoding in the conscious brain have also been observed in the unconscious brain (Sullivan et al. 2015), suggesting that meaning might be layered, peripheral, and multiplicative in an olfactory feedback system.

Because it is an emotionally evocative and dimensional mechanism for relaying information, its usage has grown in design and HCI as a medium for interfaces. While olfactory output in multime-

dia has been around since the 1960’s (Heilig 1963), Kaye (2001) developed the first theoretical framework for scent in HCI through extensive research and explorations such as ‘Smell Reminder’ (Kaye 2001), an olfactory notification system, and ‘Honey, I’m Home’ (Kaye 2004), a personal messaging system. Similarly, Strong and Gaver (1996) challenged the dominance of sight, sound and touch in HCI with their exploration of an olfactory interface for initiating communication between loved ones who are apart. Since these early explorations, olfactory interfaces have remained oriented towards interpersonal communications and immersive media experiences, but have become smaller and mobile (e.g. a pair of glasses (Choi et al., 2011) or a necklace (Dobbelstein, Herrdum and Rukzio, 2017). Further works have used olfactory data output in the field of mental health: Amores and Maes (2017) developed ‘Essence’, a bio-sensing necklace and mobile app to influence mood and cognitive performance, and Tillotson’s (2002) evocative prototype ‘SmartSecondSkin’ is a scent delivering garment for mental wellbeing.

Rep(AIR) adds to this growing field by offering a detailed account of a functional stand-alone scent interface. Furthermore, Rep(AIR) is uniquely concerned with direct communication of the need for the repair, maintenance, or care of another object rather than ambient communication between humans, as with most examples above. Rep(AIR)’s olfactory feedback is aimed at eliciting explicit action rather than stimulating a biological, or emotional shift.

Interaction design and bicycles

Furthermore, we note some previous works at the intersection of interaction design and bicycles. For instance, Pielot et al. (2012) and Steltenpohl and Bouwer (2013) focused their research on exploring haptic wayfinding interfaces for vacationers on an island and in a city (respectively). These interfaces pivot away from visual interfaces which are distracting, dangerous, and require at least one hand to zoom or re-orient. Similarly motivated, Rowland et al. (2009) developed two immersive audio-based interventions for cyclists where safety concerns remained a key insight of their analysis. They argue interfaces should encourage cyclists to stop when direct manipulation is required, asserting that ‘content delivered at the wrong time will at best be ignored’ (Rowland et al. 2009). This is an interesting point of departure from the peripherally lingering olfactory output of Rep(AIR) where, when the scent is not immediately attended to it has the capacity to resonate in the subconscious where it might still have an effect—even while being ‘ignored’.

Methods

We use an autobiographical design approach to investigate our research question. Autobiographical design is the design and genuine use of a system for and by the design researcher (Neustaedter and Sengers 2012). In autobiographical design, insights are drawn from the first-person experience of building and using an artifact or system. This method has proven beneficial in cases where access to participants is difficult, because it needs to be ongoing over a long period of time, or because the context of the inquiry is personal, intimate, and difficult to enter. The benefits of using autobiographical design include the possibility to design a fully tailored design product for the participant and their situation, to rapidly iterate on the built prototype since the designer, the maker, and the user are the same person, and to gather rich and thorough data by being in direct contact with the situation (Neustaedter and Sengers 2012). While there are challenges in using autobiographical design (Desjardins and Ball 2018), investigating the subtle and intimate maintenance relationship between a person and their bicycle was a research endeavor well aligned with the qualities of autobiographical design.

Rep(AIR) was designed as an artifact to be experienced as-is as a means to investigate a research question. The level of finish on its form, materials, and behavior, and the robustness and reparability of the prototype allowed Key to fully live with and experience the artifact during her cycle touring trips. Rep(AIR) was designed with the intention of asking a question—what relationship qualities emerge when we pay more attention to acts of repair and maintenance?—yet it was also designed to satisfy the genuine curiosity and imagination of Key.

Deployment

Rep(AIR) traveled with Key on an international bikepacking (self-supported mountain bike ride/camping) trip to Mongolia and Slovenia. Key and her partner rode 300 miles over 6 days in Mongolia, then she rode 270 miles over 6 days in Slovenia alone. During each trip, Key took notes in the probe notebook for everyday of riding. During the 6 days in Mongolia, 4 acts of repair, maintenance or care were made to Key’s bicycle, and one on her partner’s bicycle; during the 6 days in Slovenia, 5 acts of repair, maintenance or care were made. While different from an everyday commute, international bicycle travel—where resources are limited, conditions are challenging, and repairs are time sensitive—makes for a rich space to investigate a relationship to maintenance with a personal object.



Figure 2a, b, c, d. Deploying Rep(AIR): a) Dousing the spools of wool with essential oil; b) Connecting the sensors in Mongolia c) Rep(AIR) in everyday use d) Key reflecting in the tent.

Probe Notebook

In addition to using Rep(AIR) on her trips, Key also developed a daily probe notebook to ensure continuous and thorough data collection about the experience of riding with Rep(AIR). The daily probe notebook was designed as a tool to reflect on the research question by providing a physical structure and specific provocations for recording and collecting data. It consisted of three elements: a daily Inspection Report page (fig. 3c), a daily Notes page (fig.3a), and a Deeper Reflections page every third spread (fig.3b).

The probe notebook included one month's worth of full color pages, was covered in canary yellow cardboard, and bound with yellow thread.



Figure 3a,b,c. Probe notebook: a) Notes page where space was provided to use the HP Sprocket Photo Printer for photo documentation; b) Deeper Reflections page; c) Inspection Report page where inspiration came from rental car inspection procedures, including a simplified diagram of the bicycle in pink with blue instructions.

Data Analysis

Key collected data during the ideation, fabrication, prototype building, and beta deployment phases through scans, photographs, and notes. In addition, Key collected 9 reported acts of repair in the probe notebook, which included written thoughts, diagram annotations, and photographs. We conducted a thematic analysis to identify common patterns across the data. We coded the data along initial emergent themes such as exposing the life of the object, time displacement, and trust. After reviewing the data along those themes, we refined our final set of findings under three general areas. We present the findings of our analysis below, after first detailing the Rep(AIR) system.

System Description

Rep(AIR) is an impact-triggered scent diffuser mounted to the handlebars of a mountain bike. Its polystyrene housing is a 5-inch-wide by 8-inch-tall cylinder with a concave lid with a star shaped opening for scent to escape. The housing faces outward, angled up towards the rider's face and is attached to the handlebars of a bicycle with a Velcro strap. Inside the housing are three battery powered fans which, when activated, each blow air over spools of wool doused in a different essential oil and controlled by an Arduino microprocessor.

To capture impact to the bicycle, piezoelectric discs were placed at various areas along the frame which frequently see damage (fig. 6). Each sensor was calibrated individually to balance the material properties of its placement on the bike (more or less dense steel tubing) and its tolerance (how critical is this area of the bicycle). Balancing these two aspects of the system to make the olfactory feedback contextually relevant required manual calibration of each sensor.

The scents chosen were meaningful to Key: Cedarwood evokes a sense of accumulated use as it smells like old books and is diffused when a mild impact is sensed. Cinnamon evokes a sense of urgency as it opens up the sinuses and is diffused when a major impact is sensed. Eucalyptus evokes a sense of a longer timescale as it is a reminder of growing up on the California coast and is diffused every 10th diffusion and runs for 10 milliseconds longer each time, so as the bike ages the eucalyptus scent lingers for longer.

Rep(AIR)'s finish balances an attention to aesthetic detail, color, shape, as well as fit: it was aesthetically tailored and physically positioned to its rider alone. All code was tested on the intended bicycle, with the intended rider, and adapted for such. This is not to say that the system might not work in another situation but meant to emphasize the bespoke nature of the process of building this object to reflect its purpose.

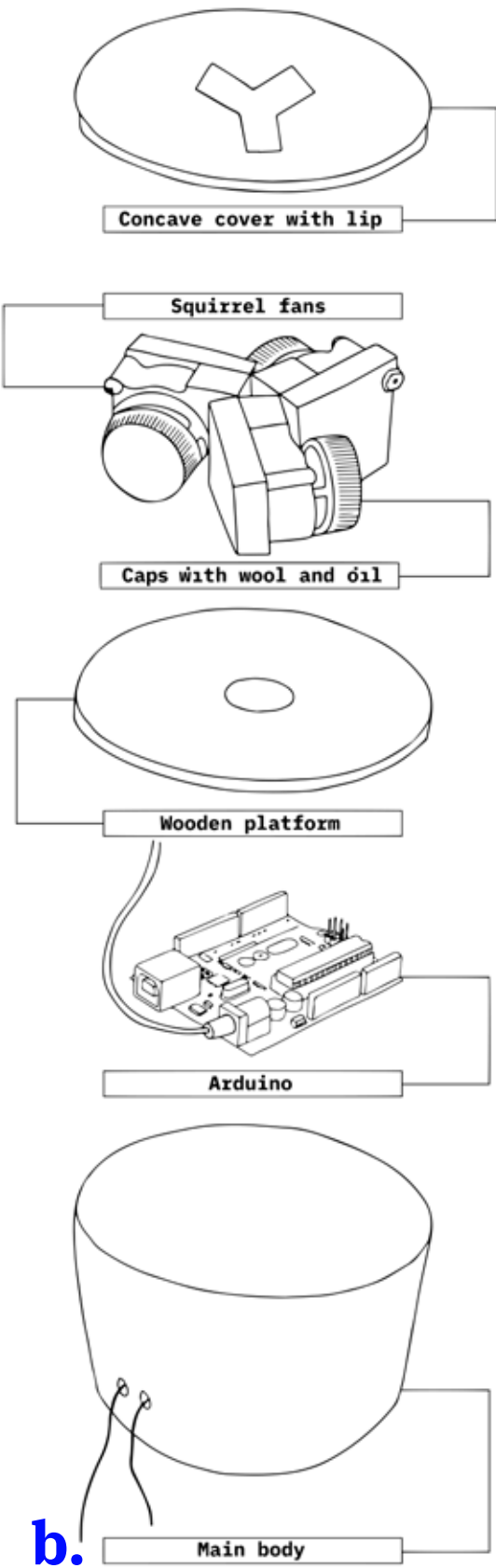


Figure 4a,b. Rep(AIR) detail: a) Three 12V squirrel cage fans attach to a wood base, three plastic caps filled with a spool of essential oil soaked wool screws into a plastic base allowing proper air intake over the fan blades; b) Exploded view of the main parts demonstrating how they fit together.



Figure 5. Housing: Sheets of white polystyrene were vacuum molded, hand molded, and textured creating a clean bright outward appearance. The hand cut lid was meant to abstractly resemble a flower.

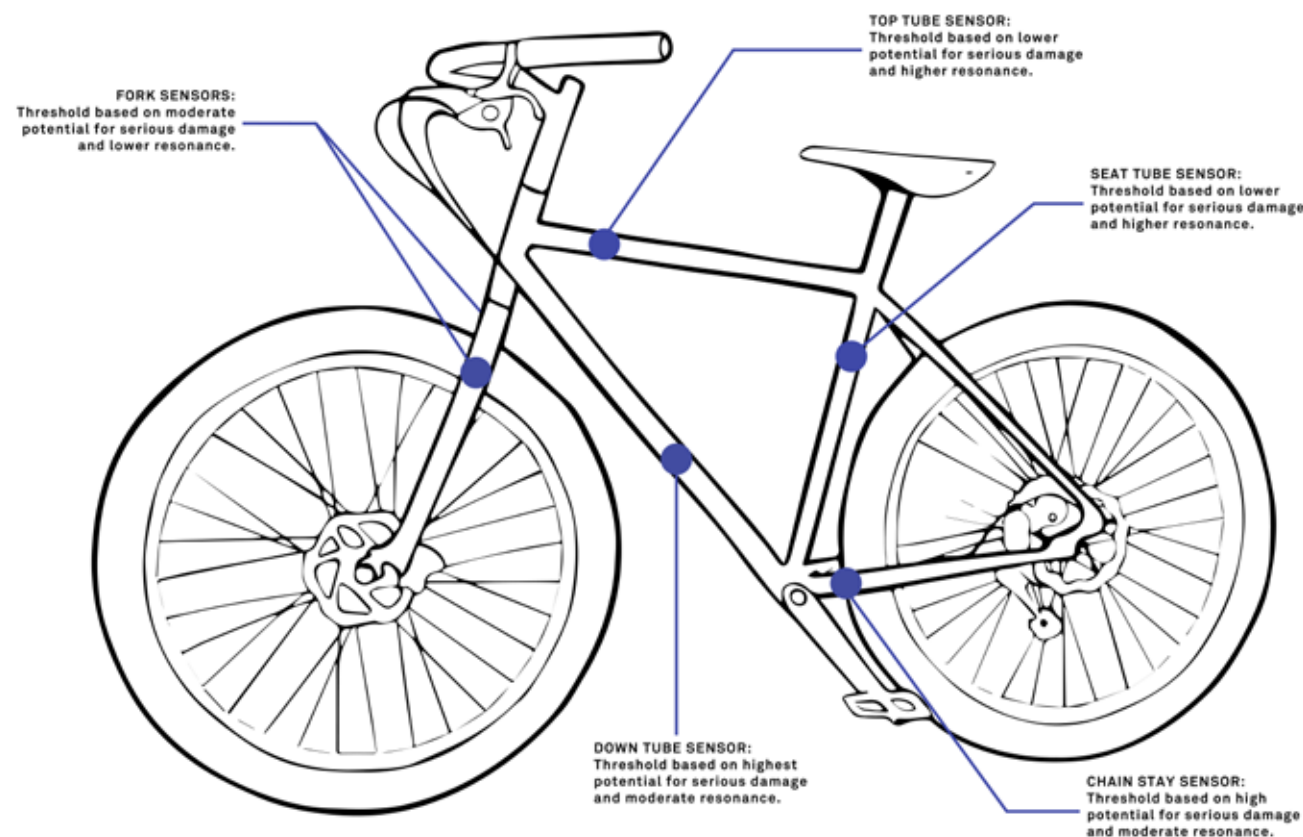


Figure 6. Sensor diagram: piezo discs (represented by blue dots) were placed along the frame where damage frequently occurs and were individually calibrated.

Analysis: Elevating Acts Of Maintenance And Care

In this section we begin by discussing how Rep(AIR) provoked focused and peripheral tactics to elevate acts of maintenance and care. We then present two qualities of the relationship between Key and her bicycle which were revealed and nurtured through this process. These qualities point towards a relationship with objects where care, preservation, and agency are complimentary counterparts to function.

A catalyst for attention—focused and peripheral

During the 12 day deployment of Rep(AIR), 9 acts of repair, maintenance, or care were made. Some were minor fixes like adjusting a dérailleur cable, others required more time and ingenuity such as using a piece of discarded car tire to plug a leaky valve. Some were attended to as a direct result of olfactory feedback, but some came about through other means. However, the presence of Rep(AIR), in all cases, directed attention to these acts by either focused or peripheral means and reflectively oriented perception within those moments.

Action through olfactory feedback

Although scent, in this case, is an ambiguous representation of damage, it effectively communicated the need for attention. For example, during the deployment in Mongolia, Key noted: *“the bike fell over today, and I got cinnamon...it further damaged the rack and pushed the strut into the tire...it took a lot of investigation to find the issue.”* On another occasion, while riding over a section of trail where many large roots traversed the path, Rep(AIR) triggered a cedarwood diffusion. *“The scent made me pause the audiobook and check-in on the bike. I noticed a bit more rubbing on the tire from the previous day. Another adjustment fixed it. I might not have noticed as soon if it weren’t for the Rep(AIR) bringing the idea of maintenance back into my mind.”* In this case, what initially triggered the cedarwood was not the tire rubbing (but the large roots) and yet the olfactory feedback led directly, though unintentionally, to an act of repair (fig. 7).

The emotional associations afforded by the use of scent also helped direct attention immediately; in her notes, Key comments *‘the cinnamon overpowers... it’s alarming at first until you realize what’s happening.’* These examples show how Rep(AIR) functioned as intended: by using scent as a way to focus Key’s attention to care and maintenance issues while riding.

Reflection through delayed investigation

In the examples above we see how attention was directed towards potential damage immediately, but because stopping to investigate what might have caused the olfactory feedback was not always practical, thoughts of maintenance and repair tended

to linger in Key’s mind. For example, in Mongolia when descending a mountain pass on a steep trail badly washed out by a recent rain storm, Key recalled smelling Rep(AIR) *“wice during very rough descents on single track today, both cinnamon, but I was in no position to check it out.”* In conditions like these, dedicating focused attention to a scent is at least impractical and at most dangerous. However, this does not erase the knowledge that some breakage has occurred, it simply redirects it to the periphery of the mind. Earlier on that trip, when reflecting on the method, Key remarked on the un-feasibility of stopping to write in the probe notebook every time she had thoughts of maintenance, saying *“Maintenance is on my mind all day, but I can’t stop to order them or pay much attention.”* The constraints of the situation meant that reflections were confined to the quiet moments inside the tent at night or early morning (fig. 2d) and that daily ruminations were forced to steep in the conscious and subconscious meanderings of the mind. On the last page of the probe notebook, when reflecting on the delay between scent and documentation, Key succinctly concluded that *“the delayed scent is cool - it’s curious, investigative, inviting more questions.”* Because of the delays in both making and documenting repairs, thoughts of maintenance and its effect on the relationship between bicycle and rider extended over a longer time period, inviting different questions, reflections, and heightening the rider’s curiosity.



Figure 7. Site of repair: A cracked and bent front rack caused rubbing on the tire, Rep(AIR) diffused cinnamon to communicate the impact.

Awareness through its actuality

Rep(AIR)'s physical presence on the handlebars of the bicycle brought attention to, and over time became a symbol of, its intended function: elevating acts of maintenance. Even while not actively diffusing scent, Rep(AIR) served as a reminder to consider wear and tear as it was happening. Key notes: *"Although Rep(AIR) was off today (due to heavy rain) I was more attentive to any new sounds or feelings. The project itself has me more repair minded."* During the first deployment in Mongolia, Key distressed over the difficulty in drawing a clear line between cause and effect with the project, writing *"it's hard to separate the design/repair/diffusion effects. It's creating more awareness but what's doing that?"* Although the lineages of causation remained difficult to trace throughout the rest of that trip and the next, the subliminal usefulness of the artifact solidified as Key came to see and use it as an icon as well as an interface: *"came to use other kinds of interactions with it to drive thought about repair. It became much more symbolic. It's like the rubber band on your wrist that reminds you not to smoke or whatever. It's aiding in maintenance indirectly."* In this way Rep(AIR) as an icon was kept alive through each activation as well as through acts of maintenance on the device itself.

These three tactics for awareness became important modes with which to engage in the research question and goal of the inquiry. Some were planned and explicit, others emerged over time as natural responses to constraints in the environment and were ambient. By adapting the usage of Rep(AIR) to suit her needs and situation, Key was more flexibly equipped to reflect on emergent qualities of the relationship with her bicycle, as described in the sections below.

Shared stories—the bike experiences too

The stories of living on and traveling with a bicycle constitute a rich accumulation of experiences for both the rider and her bicycle. In this section we discuss how acts of maintenance and care reveal those non-human parts of the story typically unseen and how this added dimension extends the appreciation of a thing to fundamentally draw the human and the thing closer. We reveal two emergent behaviors which surfaced signs of those experiences outside of human perception through reunions after time apart and through a ritual of bathing and inspection.

Investigative reunions

Over the length of the trip the bicycle was packed, shipped, and unpacked half a dozen times. At each leg of the journey the bicycle would have to be taken apart for transport then rebuilt once it landed in the new destination. Each of these events became an opportunity to carefully inspect the bicycle.

These investigations were focused on what damage had occurred in transit (while Key was comfortably in her seat eating peanuts) or for damage Key missed while riding. This was in some ways a pragmatic practice—uncovering potentially critical damage is self-serving, but in reality, the motive came more from curiosity than a fear: *"This is the frame damage I noticed when unpacking the bike before. I didn't have time to investigate a bunch that day, but I thought a lot about it today. I really would like to figure this out."* In this instance, Rep(AIR) was not actively tracking, and Key was not there to witness these breakages, yet the investigation itself was an intimate exposing of the bicycle's experience in parallel to the rider's. Although this investigation was not prompted directly from Rep(AIR), Key's more mindful and inquisitive attitude towards wear and tear on the bicycle most certainly was.

Ritual care

On several occasions throughout the journey the opportunity arose to bathe the bicycle, and in some cases thoroughly clean its various components. This served to expose additional wear and tear, but also to reciprocate care for the object which was the rider's literal, and at times emotional, support. When remarking on a particularly symbolic bath conducted in the *"deep puddle" of a parking lot*, Key wrote *"This does not improve function - it's not even profoundly different, but it just feels good to do"* (fig. 8). The desire to give back and acknowledge the existence of an object extended beyond moments of convenience, as when Key recalled, *"I had a dream last night that I got back to my hotel, in between trips, and put Cal [the bicycle's nickname] in the shower, haha."*



Figure 8. Bathing ritual: Key bathes her bike with care in a puddle.

I wanted to do something nice and make her shiny. Very appreciative of her today." Bathing became a ritual of investigation but more so a celebration of shared accomplishments by recognizing the individual role the bike played in the journey. This was apparent in the last bath of the trip when Key expressed her gratitude by noting: *"Removed all parts for deep cleaning. Felt good to give her a proper cleaning though. She earned it."*

Through seeing the bicycle as an entity whose experiences are interwoven, overlapping, but also independent of the rider's, the stories created about each trip are enriched with a second, non-human perspective. By using maintenance and care to distinguish or celebrate the bicycle's individual existence, wear and tear become meaningful physical traces like battle scars which symbolize this parallel life. Bringing emphasis to those marks can then be a powerful tool to see that objects exist apart from us as well as with us, that they shape us as well as are shaped by us.

A collaborative existence—flattening the relationship hierarchy

In the previous section we discussed how viewing the bicycle as an entity with its own experiences can affect its relationship to the rider. Here we bring to light the entity which is the bicycle and rider together. In these examples we show how maintenance and care foster and strengthen a non-hierarchical exchange which manifests itself alongside its constituent parts.

Through teamwork

One of the most salient evolutions seen in the analysis of the probe notebook was how the bicycle went from a tool to a team member. This change was gradual; not a conscious desire, but an other-ly force born of many factors of which repair and care were foundational. On the first day in Slovenia Key describes how this bond began to emerge, *"This was my first day alone with Cal and Rep(AIR) and it seemed different. When I noticed a strange sound and fixed and diagnosed it right away I was so proud, and I just felt more connected to Cal. As if I relied on her more. I am just generally more in tune with her today. Maybe it's because I am relying solely on her and my ability to fix her... either way it is being expressed through maintenance and repair."* Key took pride in being able to repair the bicycle but even more so in her ability to quickly diagnose the issue. This intimacy of knowledge is directly related to the combined prior acts of maintenance, investigation, and awareness. This particular act of repair illuminated for her how that intimacy of knowledge was strengthening their connection.

Later during that same trip, after a particularly harrowing incident, this nascent understanding of how the bicycle and rider can operate as one was solidified. Key details the event in the probe notebook: *"Today was crazy, just nuts. It was a very weird powerful bonding day for me...on the biggest dirt descent I've ever seen a massive storm hits. Hail, rain, lightning, etc. I was legitimately scared. For hours I was repeating the mantra 'we will get down this mountain'. At the bottom, back on pavement I let myself feel for a minute - I was so thankful for Cal, so proud that we made it. So thankful that it worked, it survived, it saved me! I really felt like we were going through this together."* During this descent Rep(AIR)'s olfactory communications were dampened by its rainproof plastic cover (fig. 9), and yet it periodically entered the mind of Key as she worried that it too might be damaged in the storm. Once safely down, drying in the tent at night and reflecting on this event, she realized how much she relied on and trusted her bicycle to do its part in getting them both down the mountain. This trust was largely built through making repairs and adjustments, such as filing down and cleaning the brakes the day before (making them more suited for a steep descent), having that fitness tested, and succeeding. The account of this descent illustrates how trust in the rider-bicycle team superseded that of the individuals as they operated as a unit to survive the event.



Figure 9. Rep(AIR) covered: The waterproof bag dampened but did not eliminate communication.

Through empowerment

As Key rode with, repaired, maintained, and cared for her bicycle, their collective skill developed. They collaborated to strengthen their mutual ability: the bicycle affording muscle development for the rider, and the rider adjusting and maintaining the bicycle's fitness for the current terrain. From that co-created capability grew an empowerment to accomplish ever more challenging undertakings.

In reflecting on the emotional aftermath of the stormy descent mentioned above, Key recalled *"Today seemed sweeter because of the storm. As shitty as it was it was empowering. I feel like me and this bike can handle anything."* Not only did Key feel like she and her bicycle were acting as a team, she felt empowered by that relationship, that as a team they could accomplish more than as an individual using a tool—even a powerful and well adapted one. As acts of repair and maintenance physically attuned the bicycle to Key and created an intimate knowledge of how they operated as a team, the bicycle, at times, became an extension of the rider rather than a separate entity. An account in the probe notebook illustrates this well: *"The first half of the day was just brilliant riding. Me and Cal were fused - responsive, efficient, climbing huge hills, everything fabulous."* Every act of repair maintenance, and care moved the bicycle physically and emotionally closer to Key. The net effect was a different mental model with which to see her bicycle—as no longer a bicycle and a self, but an empowered us. On the last day of riding, Key describes a moment of empowerment where she expressly acknowledged the emergence of this third entity: *"Last entry - weird, this trip was quite different than the last in terms of relationship building. When I got in to town and had time to spare before meeting with Airbnb I rode around. Came across a set of cobbled steps and, fully loaded, thought 'we can do that'. There is an invincibility that's emerged. An identity too."* Over the course of the two deployments and all the packing and unpacking in between, Key's relationship with the bicycle evolved into something more cohesive, and identifiable.

Through these examples we see how Rep(AIR) catalyzed renewed and reflective attention to acts of maintenance and care, and how over time those became ways to acknowledge and reinforce the mutuality of the relationship's evolution into an amalgamated existence. As this relationship developed, maintenance shifted to be not only self-serving, or even as a means to express appreciation for what the bicycle brings to the experience, but to maintaining the relationship itself. As Key expressed in a probe notebook entry, *"You want to fix it to get it working again - but something changes, and you want to fix it for other reasons."* Likewise, as Key's relationship to Rep(AIR) developed, olfactory feed-

back shifted to be not only about surfacing breakage and wear but to continuously and peripherally supporting that relationship development.

Discussion

Our findings show how Rep(AIR) brought to the foreground moments of breakage, ongoing wear, maintenance, and repair acts. Below we discuss how Rep(AIR) and our autobiographical design inquiry opens up new understandings regarding practices of repair with a focus on ongoing processes of breakage. In addition, we discuss the more fitted relationship that has emerged overtime between the rider and the bicycle, in part supported by ongoing acts of maintenance.

An ongoing process

Rep(AIR) was a catalyst to think about repair while Key was riding. While our original intention was to document discrete moments of repair, we found that Rep(AIR) instead focused attention to the ongoing processes of wear and tear, breakage and eventually repair. Our work adds nuance to current discussions about repair in design and HCI which often portray repair as an act that begins once an artifact is broken. Our findings certainly point to clearly defined moments of active repair, but importantly show how they are inherently part of a longer history and at times a peripheral awareness of breakages and use. By better understanding the slow and accumulative wear and tear on the bicycle, moments of maintenance and care likely prevented some more unexpected breakdowns. Simultaneously, tracking the decay of some parts of the bicycle meant that breakages didn't come as a surprise, but were expected and could explicitly be mitigated, as when, after the audiobook incident mentioned above, Key decided to replace the damaged rack for fear it would degrade the tire and cause a flat. Our aim is not to display an 'idealized' process of repair; our findings also highlight the challenging parts of this process. For instance, finding the cause of a particular worn area took time and investigation—suggesting that repair is not only the physical act of replacing a part or rearranging material, but also includes an inquisitive practice. The ways in which maintenance was on Key's mind all day, how smells lingered and hinted at ongoing wear, or how deeper repair investigations were delayed, start to paint a different narrative around how breakage and repair can happen when there is an ongoing path of communication between object and human.

A more fitted relationship

Part of our study was to investigate the qualities of the relationship that would emerge if we paid more attention to care and repair. Our findings, particularly the last two qualities, point to a strong

bond and a flattened hierarchy between bicycle and rider. We found that repair not only restored or enhanced some functionality of the bicycle, it also made it more attuned to its rider, in a piecemeal process. Functionality, in this sense, was not abstracted to the bicycle alone, but in fact depended on a good fit with the rider. This echoes and expands Maestri and Wakkary's idea of 'adaptation' (2011) as well as Odom et al.'s notion of 'augmentation' (2009), where both concepts articulate how repair might change the original function of an object. Our case, however, shows that although the basic working function of the object was not dramatically transformed, the very definition of functionality was. As parts were subtly adjusted towards a better fit between the human-object team its meaning grew to encompass that relationship.

While on one hand the bicycle is being adapted to fit the rider, on the other hand care and maintenance also bring the rider closer to the bicycle's own experience (as seen in 'Shared Stories - the bike experiences too'). Hence, repairs and maintenance are factors which might close the gap between human and object, starting to erase the hierarchical relationship between the two and opening a space for a collaborative relationship to develop in parallel to individual experience. While previous works around repair in HCI have surfaced narratives of empowerment by engaging with repair communities, learning about technology, or using repair tools, our work reveals empowerment through the relation to the artifact itself and through the newly formed human-object team.

Conclusion

In this paper, we presented Rep(AIR), an olfactory interface that brings attention to wear and breakage on a bicycle. Key's autobiographical design inquiry, culminating in 12 days of bicycle touring with Rep(AIR), has offered rich and nuanced insights into how paying more attention to breakage over time and ongoing repairs can lead to a renewed understanding of repair, and to the description of a more fitted relationship with an artifact (through ritual care, teamwork, and investigative reunions, for example).

We wish to conclude with a reflection on the voice that was given to the bicycle through Rep(AIR). Akin to artifact-oriented findings in research approaches like Thing Ethnography and Interview with Things (Giaccardi et al. 2016; Chang et al. 2017), our approach to sensing and translating the bicycle's data into scents supported a new expression of its wear during daily use. This example points to the possibility of engaging in 'conversations' with more artifacts in our everyday lives. As a result, we might ask: how would we change the

way we use and care for things if we knew more about their experiences of wear and breakages? This new channel of communication might also be an appropriate approach to actively recognize the ongoing changes that artifacts experience—changes that contribute to their wabi-sabi. By constantly 'listening' to artifacts, we, as humans, might become more aware that they won't last, they are not finished, and that they are not perfect. This might also prompt and encourage ongoing, caring, and inquisitive practices around the maintenance and repair of everyday artifacts.

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