Indoor Weather Stations: Investigating a Ludic Approach to Environmental HCI Through Batch Prototyping

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ABSTRACT

In this project, we investigated how a ludic approach might open new possibilities for environmental HCI by designing three related devices that encourage environmental awareness while eschewing utilitarian or persuasive agendas. In addition, we extended our methodological approach by batch-producing multiple copies of each device and deploying them to 20 households for several months, gathering a range of accounts about how people engaged and used them. The devices, collectively called the 'Indoor Weather Stations', reveal the home's microclimate by highlighting small gusts of wind, the colour of ambient light, and temperature differentials within the home. We found that participants initially tended to relate to the devices in line with two 'orienting narratives' of environmental tools or ludic designs, finding the devices disappointing from either perspective. Most of our participants showed lingering affection for the devices, however, for a variety of reasons. We discuss the implications of this 'sporadic interaction', and the more general lessons from the project, both for environmental HCI and ludic design.

Author Keywords
Research through design; environmental HCI; ludic design; ubiquitous computing; sensing

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design

INTRODUCTION
This paper describes our batch production and deployment of a set of three related designs that highlight the home's microclimate, undertaken to explore a ludic approach to matters of the environment as an alternative to utilitarian or persuasive approaches. A ludic approach to technology design opens up issues to disrupt their reduction to singular narratives. For example, a ludic approach to domestic technology undermines assumptions about 'smart' appliances for the efficient and productive home and presents instead curious systems for exploration and reflection about domestic space [12]. Here we present a ludic approach to designing technology for the environment offering insights into both the development of environmental HCI as a design space and ludic design as an approach.

Opening Up Technology for the Environment
Over the last several years, there has been a growing tendency in HCI to how digital technologies might address environmental issues, for example by making computing more environmentally sustainable [e.g. 2, 31] or, more commonly, promoting 'greener' behaviour on the part of users [e.g.10, 11, 20]. As DiSalvo et al. [7] point out, most of this research works with the logic of persuasive technology, seeking to present information to users in a way that encourages 'correct' behaviour.

There are several challenges to persuasive approaches to environmental issues, e.g. as manifested by resource demand monitors. First, empirical studies indicate that interventions have limited effectiveness [1], producing minor and/or short-lived behaviour changes, for example, or 'boomerang' effects where reduction by some is offset by increased consumption by others [26]. Moreover, critical reflections from social sciences, humanities and the arts, point out broader assumptions and limitations of demand reduction strategies. For instance, Shove [27] paints a compelling picture of how resource use is deeply interwoven with cultural assumptions about cleanliness and consumption. Strengers [28] builds on this, drawing on Bourdieu's [5] notion of 'habitus' and pointing out the constraints many people face in reducing their resource consumption. Dourish [8] points out that the tendency for

most environmental HCI work to focus on individual behaviour change reflects the market logic of individual rational actors, and draws attention to the blind spots of this logic, while Brynjarsdóttir et al [6] generalise this argument to link to modernism and its limitations.

Partly inspired by these social, political and cultural critiques, we endeavored to apply a ludic design approach to disrupt the unitary logic of demand reduction technologies. We noted that the uncompromising narrative of ethical sacrifice becomes aversive to people tired of blame and guilt, reifies assumptions about the 'people' and 'the environment' [8], and obscures questions of authority over the discourse they embody [5]. Instead, we sought to create artefacts that complicate simple narratives of responsibility and disrupt a dogmatic logic of self-sacrifice. We wished to encourage people to explore questions about their relationship with the environment but without imposing a pre-established sense of what the right and wrong answers are.

Opening Up Ludic Design
Along with our objective of opening new perspectives on environmental HCI, we also wanted to develop ludic design as a practice. We hoped that applying resources such as *ambiguity* and *interpretation* [14] to the critical and complicated issues of the environment would demonstrate that the playful approach of ludic design does not imply frivolity, but instead that exploration, surprise, improvisation and wonder can be useful tools in approaching complex and serious issues.

In addition, we set out to explore *sensor legibility* [15] as a resource for meaning making. In a previous sensor related project for the home, we had erred on the side of sensors being too opaque, and output thus seeming obvious or wrong [15]. We saw this as an instance of the more general challenge of finding a sweet spot between banality and incomprehensibility. Provocation requires a level of defamiliarization, but this fails if devices are either too familiar, or too alien. In this project, we hoped that making the operation of sensors locally apparent would support people in approaching an unusual system.

Another goal for this project was to test our perception that ludic designs afford multiple perspectives. Whereas in the past, we have sought multiple interpretations of one or a few deployments, for this project we wanted to support multiple views about multiple deployments. In recent environmental HCI work around participatory sensing, citizen science and crowd sourcing [e.g. 10, 11, 21, 22, 25, 28], large numbers of people are drawn into the research and design agenda. Our intention is of a similar spirit, although not toward galvanizing a majority of opinion and behaviour but toward allowing the diversity and richness of multiple views to emerge. Therefore, we proposed to both *batch produce* multiple devices, on the scale of 10-100 devices, and *batch deploy* them to multiple settings, in this case a target of 20 households.

Ludic Design for Environmental HCI
With this dual focus on advancing ludic design and opening environmental HCI, we began our design process.

Space precludes a full account (some details may be found in [4] and [19]) but we highlight some of the ways that our overall objectives informed our eventual design.

Our design process involved many months of delving into the kinds of critical literature described above as well as familiarizing ourselves with a range of environmental issues and responses, from governmental initiatives to grassroots efforts. We conducted two novel Probe studies with several households to understand narrative accounts of energy in the home. Parallel to all these investigations we considered over a hundred historical and contemporary art projects regarding the environment. This survey allowed us to compare art projects that used an aesthetic approach to resource demand monitoring, such as the Power Aware Cord [18] and the Wattson meter (www.diykyoto.com), and projects that used an aesthetic approach in a more open-ended or disruptive manner. The Energy Curtain [9], for instance, creates a conflict rather than advocating a course of action: its owners must choose between closing it on a sunny day so its solar cells can collect energy, or leaving it open to enjoy the natural light.

We were also inspired by contemporary artworks that explore appreciation of environmental aesthetics more directly. For example, Felix Hess makes the swirls and eddies of local drafts visible with arrays of small weathervanes mounted on floors or ceilings [18]. Ackroyd & Harvey covered one of the National Theatre's buildings with grass, suggesting (ackroydandharvey.com/flytower/) that as it faded "it [would] be hard not to think about global warming". Tim Knowles (www.timknowles.co.uk) attaches pencils to the tips of tree branches to produce drawings influenced by the weather. In these works, the sensors – i.e. the weathervanes, the grass, and the tree branches – simultaneously act as the output displays, offering the kind of legibility we wanted to achieve.

Reflecting on these examples, we gravitated toward seeing the home as an instance of 'the environment', imagining that just as someone might reflect upon the rhythms of a natural (and large-scale) landscape like the Grand Canyon, so too might it be possible to reflect on the climactic patterns of one's domestic space, where the noticeable blurs into the unnoticeable and both aesthetic and instrumental appreciation may be evoked. Similar to Hess's weathervanes, we wanted our systems to be small but noticeable, legible but depicting patterns easily ignored or unavailable, batch produced yet still beautiful and curious to behold. We wanted them to intervene in the home climate while becoming part of it. Thus we set about exploring ways that we might build devices that expose *the microclimate of the home* as a topic relevant equally for environmental concern (are there draughts? should we turn down the heating?) and as a domain of aesthetic appreciation (isn't the ambient light beautiful? where are the home's tropical regions?).

THE INDOOR WEATHER STATIONS
Space constraints preclude a detailed account of the process that led from our basic design concept to the realised designs. The process featured innumerable discussions and meetings, the production of six substantial

design workbooks [13], sensor tests in the project team's homes, a publicly deployed design experiment, material and electronics tests, and the invention of new processes and tools including a custom fitting that is currently being patented. The result, finally, was three distinct devices collectively referred to as the Indoor Weather Stations: Wind Tunnel, Temperature Tape, and Light Collector.

Wind Tunnel

The Wind Tunnel makes salient the almost imperceptible wind currents of the home. The device consists of a stylized 'forest', made of paper film cut into delicate shapes, enclosed by a transparent, semi-cylindrical canopy. The forest is built on a base, containing electronics to be described later, that allows the device to rest on any flat surface. From one end of the base a tall 'chimney' projects upwards. At its top a wind-sensor, protected by a slotted orange housing, measures tiny gusts of air near the device. This controls a small fan inside the forest's enclosure, which amplifies the gusts to create miniature storms that visibly buffet the 'trees'.

The Wind Tunnel shares two interactional features with all the Weather Stations. On one end (visible in Figure 1) is the *last day* button. When pressed, this reads back through the last 24 hours of logged sensor data, recreating the storms over about two minutes. This allows people to see what the device has been doing in their absence, or overnight. On the other side of the device, under the chimney, the *lull* button stops the output of the device (in this case, the fan), while allowing it to continue collecting data. This is to allow people to stop activities that may be disturbing, e.g. when sleeping. The lull button pauses output for 8 hours, after which it automatically resumes.

Temperature Tape

The Temperature Tape gives people a sense of temperature gradients within the home. Two lengths of 2.5 metre long fabric ribbon can be wound around or extended from the circular body of the device. The ribbons contain cables that connect to temperature sensors embedded in a plastic hook on one end, and eye on the other. The difference in readings between these sensors is shown by a needle dial on the main body of the device; the needle swings towards the warmer side, with a gauge indicating the relative difference in temperatures. The total span of 5 metres is long enough to allow temperature differences to be measured from floor to ceiling, along stairwells, or between different rooms. In addition, each ribbon is screenprinted with stripes of layered thermochromic ink, arranged so that they fade from yellow to orange to red to black between about 15° - 25° C, to make visible temperature variations along the ribbons' length. Like the Windtunnel, the Tape has both last day and lull buttons.

The Light Collector

The Light Collector shows a history of the changing ambient light colour in the home. The device consists of a small bottle-like main body with a cup shaped 'funnel' on its top. The funnel, which is lined with copper leaf, resembles a radio telescope or radar dish. Inside the base of the funnel is a light sensor. Every five minutes, the device recreates the colour represented by the sensor data as a 1-pixel wide coloured strip at the top of the display; earlier readings are scrolled down. In this way, the device shows a sedimented view of the last two hours of ambient light with oldest readings at the bottom, and most recent ones at the top. As with both other devices, the Light Collector has both lull and last day buttons; the latter, when pressed, causes the display to scroll upwards, revealing readings previously 'hidden' by the bottom of the screen.

Technical and Constructional Features

The three Weather Stations are clearly distinct devices, but they share a number of features that unite them as a family and which made their construction easier. Functionally, they all highlight potentially overlooked aspects of the home environment by displaying the outputs of sensor readings taken by the device. They also exhibit sensor legibility, in that they all make clear locally what sensors are reading, an alternative to the common ubiquitous computing tactic of treating sensors as black boxes

Figure 1. The Indoor Weather Stations: Temperature Tape (left), Light Collector (centre) and Wind Tunnel (right)ç
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returning data to remote applications, and one which we thought might mitigate the suspicion and feelings of intrusion which such systems have given rise to in the past.

Several constructional features link the devices as well. The casings, produced using our object printer, were largely left in a relatively unfinished state. Each device includes at least one feature, however – the copper-leafed funnel, the silkscreened ribbon cable, the lasercut 'forest' – that is notably detailed, to indicate the purposefulness of the overall aesthetic.

Each of the devices is built using the Gadgeteer platform ([29]; see also http://research.microsoft.com/en-us/projects/gadgeteer/), a spin-off of Microsoft research that allows rapid prototyping of embedded devices with a range of electronics modules. The modular nature of the hardware accelerated the initial process of experimenting with sensors, actuators and related electronics. Gadgeteer significantly simplified the development of the pieces by providing a development environment (Visual Studio) which allows on-device-debugging as well as writing the embedded software using an object-oriented programming language (C#). A common library could be developed to generically process sensor data, map sensor data to displays, to log data to SD cards, handle the lull and last day functions, and – in a second generation of the devices – to provide wifi and internet connectivity, enabling us to transmit and store the collected sensor data on a database hosted on a central server. This allowed us to access all the devices' real-time and historic data through a web interface. We also had the devices working with rechargeable batteries, but opted for deploying with wired power due to usability and reliability issues

Despite the economy of scale represented by the devices' shared features, there were significant elements of the designs that had to be handled as a matter of repeated craft making rather than batch production. For instance, each of the Light Collectors' funnels was copper leafed by hand. The Temperature Tape's ribbons were produced by screen-printing 10-metre long swathes of cloth, which were then sliced, machine-folded and sewn around ribbon cable. The Wind Tunnel's forest was produced from separate layers of laser-cut paper film, hand laminated between layers of plastic to achieve a topographical effect. These details were arguably crucial to the aesthetics of the pieces, but quite time-consuming to produce.

Batch Production and Deployment
We produced over 60 of the prototype Weatherstations, so that we could batch deploy a complete set of three to each of our 20 volunteer households. One of the reasons that trials of multiple copies of highly finished prototype devices are rare is that they are difficult to achieve. Apart from SenseCam [23] most of the studies we have reviewed use off-the-shelf hardware with occasional augmentation, whereas our approach involves producing highly finished bespoke computational devices. Batch producing and deploying such devices raised many challenges. In order to achieve the research reported here we built workshop facilities including a Dimension Elite object printer, a laser-cutter, and reflow soldering oven, as well as a team with

Figure 2. A Light Collector in situ.
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competencies in CAD software, circuit board design and fabrication, software development for embedded and cloud-based systems, product making, and considerable ingenuity. Despite this, producing the 60+ devices we report here took months even after they were specified: the work to achieve a batch deployment of this kind should not be underestimated.

THE WEATHER STATIONS IN ACTION
To make it possible for us to easily interact with participants and to investigate a sense of community, we recruited local participants via community blogs, coffee shops, and posters in a local park. We revealed that the project concerned questions of community, environment, and design. Our participants were a fairly diverse group in terms of age, backgrounds and occupation (an engineer on the London Underground, a couple working in IT systems, a linguistics analyist, an architect, an urban planner, two journalists, a social science researcher, two teaching artists, a designer, a design student, etc).

Twenty households participated, with many of the homes having more than one person using the stations. Most of the homes had had a representative at an 'orientation session' early in the project, during which they received an overview of the project and a research kit, based on the Cultural Probes [12] approach, to encourage thinking about the home in new ways and also to expose them to kinds of reflective activities that characterize the studio's work. When it came time to deploy the Weatherstations, we chose three distinct settings – their homes (7 participants), our studio (9 Ps) and a local coffeeshop (4 Ps) both for pragmatic reasons (it was impractical to hand them all over separately, but difficult to find times to meet groups of participants together) and to explore strategies for larger deployments in the future. During each handover, we reviewed the project again and introduced the stations. Various levels of interaction followed with the participants including home visits, email/telephone exchanges, and 'prompts' sent via newsletter, website or postal mail. These prompts included things such as 'significant moment forms', photo assignments, weather calendar posters

showing their stations' data for a month, and community-wide maps of data collected from the stations. At the time of writing, the Weather Stations have been deployed for over 9 months. The following sections summarise some of our main findings from these deployments.

Accommodating the Weather Stations
Without exception, participants unpacked their stations with a mix of intrigue and excitement, immediately handling the forms and experimenting with forced reactions from the devices. Nick stroked the WT referring to it as a pet. Tim commented about the LC: *"It's like a goblet, a chalice. I love things that are new and haven't quite settled down yet into what they are going to be"*. This mix of attraction and anticipation soon gave way to the task of fitting the Weather Stations into the home.

Finding a place for the Weather Stations raised a number of practical issues: obvious ones such as access to power or a flat surface to rest upon or avoiding awkwardly trailing cabling, and more complicated factors such as what different rooms might reveal or what having a weather station in a certain spot might tell visitors. Several participants described moving the stations around, partly through our encouragement, but partly to find where the stations were "happy". Sumit described how each station took on a different persona for him and this dictated their placement. The LC became a houseplant and was therefore placed amongst other carefully selected pieces in their guest room. The WT felt more like a companion device, and found its way to the dresser in his bedroom. He explained that the Weather Stations: *"have found their place…they gravitated to where they would fit. Now we don't look at them and think 'oh that looks weird' or 'that's taking up space there'."*

Some participants took the approach of deploying the stations to investigate phenomena they suspected existed in their homes, for example putting the WT to work detecting draughts in certain rooms or using the TT to determine if the baby's room really is colder than the neighboring room. Other participants hoped the stations might tell them something new. Rosie wondered, for example, if the stations would reveal some hidden secrets such as whether there were different currents at night while everyone slept.

Working with the Weather Stations
We anticipated that people would work with the Weather Stations to actively investigate the ecology of their home and make comparisons between different locations using the devices. However, after initial enthusiasm, the range of experimentation took on a slower pace than with other systems from our studio. Indeed, as the excitement of discovery wore off, participants sometimes expressed disappointment, perhaps through comparisons with other sensor technology they were familiar with. Pete, for example, felt the stations didn't hold up to the range of real time apps available for measuring *"movement, exercise, sound levels, and anything else you can think of."* Catherine contrasted the stations with her solar panel display's immediate, readable feedback about power generated. *"These,"* she said, referring to the Weather Stations, *"are a bit more secretive about their story."*

Working with the Weather Stations created some dilemmas of readability and expectation. On the one hand, they did not do enough. *"Basically, it's not telling me much I don't already know just being in my house,"* Nick told us. Catherine suspected that her dog was active during the night and, when entering the kitchen, would switch the movement-detecting lights on. This she was able to confirm by noting a series of brighter bands on the LC display. However, this was just a minor intrigue, confirming something she already suspected.

On the other hand, what the stations did divulge didn't always match expectations. Meena noted that her family had a major water leak that seemingly went undetected by the stations. Yet, other events took on too much significance without any discernable reason. In trying to make sense of her monthly weather calendar Meena said: *"It looks like we've been very belligerent. We'd like to know what we've done!"*

While the stations only marginally aroused the kind of investigative curiosity of the microclimate of the home we had expected, we found participants using them to make sense of their homes in other ways – particularly when they could see their own data over more extended time periods than the device's replay buttons allowed. While Meena and Tim were unable to decipher specific events on the calendar of LC readings (*"what caused this spike here*?"), the conversation became more animated when referring to the overall patterns she and her partner perceived. Meena joked that her house looked like a "*sludgy cave*", making her want to turn on more lights – an urge quite contrary to the energy saving motives assumed by many of the participants and an amusing irony Meena was aware of.

This mixed experience of working with the Weather Stations also arose during a field visit with Sumit. After using the stations for several months, Sumit greeted us at his door with the declaration: *"I'm afraid you will find this a negative result."* Yet the conversation quickly proceeded through interesting and desired uses of the Weather Stations. In terms of clear readability and interpretability, Sumit felt the Weather Stations missed the mark, yet he quickly questioned himself as to whether these matters were actually required. *"We have rabbits,"* he reflected, "*and they don't do anything particularly readable either. In fact, it's just this enigmatic behavior that makes them interesting*". These furry creatures, Sumit went on to say favorably, "*add a little chaos to an otherwise normal life."*

Engaging with Others
Once we began to realise that participants were not engaging with the Weather Stations in quite the manner we expected, we introduced further resources to offer a richer context in which their data might be interpreted. We had observed that the Weather Stations often acted as talking points for participants in their homes. Families and partners collectively worked with the stations, for example, and the stations were often placed conspicuously to invite visitor questions. That is, the stations and their behaviours were social interactional affairs. It seemed natural, especially considering our batch deployment strategy, to build on this and enable people, through a shared website, to view the
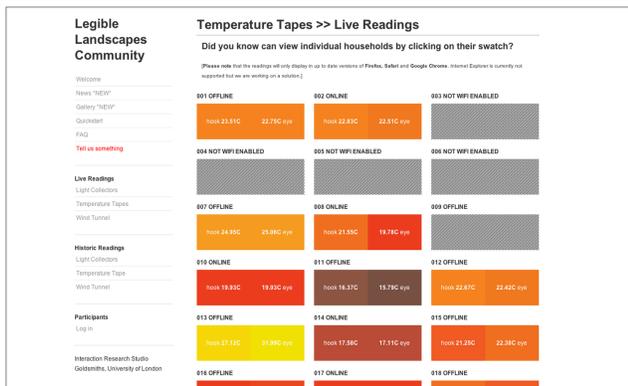
Legible
Landscapes
Community

Temperature Tapes >> Live Readings

Did you know can view individual households by clicking on their swatch?

[Please note that the readings will only display in up to date versions of Firefox, Safari and Google Chrome. Internet Explorer is currently not supported but we are working on a solution.]

Welcome
News "NEW"
Gallery "NEW"
Quickstart
FAQ
Tell us something

Live Readings
Light Collectors
Temperature Tapes
Wind Tunnel

Historic Readings
Light Collectors
Temperature Tape
Wind Tunnel

Participants
Log in

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001 OFFLINE	002 ONLINE	003 NOT WIFI ENABLED
hook 23.51C 22.75C eye	hook 22.83C 22.51C eye	
004 NOT WIFI ENABLED	005 NOT WIFI ENABLED	006 NOT WIFI ENABLED
007 OFFLINE	008 ONLINE	009 OFFLINE
hook 24.95C 25.06C eye	hook 21.55C 19.78C eye	
010 ONLINE	011 OFFLINE	012 OFFLINE
hook 19.93C 19.93C eye	hook 16.37C 15.78C eye	hook 22.97C 22.42C eye
013 OFFLINE	014 ONLINE	015 OFFLINE
hook 27.12C 31.99C eye	hook 17.58C 17.11C eye	hook 21.25C 22.38C eye
016 OFFLINE	017 ONLINE	018 OFFLINE

Figure 3. Shared and historical data is available on the web. © Interaction Research Studio

data of others. For example, Figure 3 is a screenshot of the live data from all the TTs at a single moment. The site also shows historical data for all the (anonymised) households.

Expanding the project in this way helped people find a new context of interpretation for their own data. Tim explained that awareness of the community made you look at your own stations differently. This led us to further enhance the website as a forum for commenting on each others' data, posting pictures and general project news. While Catherine joked that "*comparative data between households would be like moving back to the 'village' where everyone knows what you are up to: 'what were you doing up at 3 am'*", in practice, people tended to respond to the community in the same way as the stations, more in terms of appreciating perceptible patterns of aesthetic interest than engaging in more analytic reasoning about their own or other's data or behaviour. For example, Meena's "sludgy cave" remark became particularly salient when she compared her home with the brighter colour palettes detected by other LCs.

One of the most popular views on the website constructed a map of wind readings across households and labeled these as 'gusty', 'light breeze', or 'gale force'. Brett found this map intriguing because he had assumed, yet was mistaken, that his WT would register the windiest given its placement near a window open to heavy breezes across the Thames. "*People must be using hairdryers!*" he joked. Others indicated an affinity for this map because it was one of the first views of the data in a geographical context, potentially allowing one to see the wind or the light move across a larger landscape. Both Tim and Meena also noted a more subtle aspect of this map – not only did they see relations between their own home and neighboring ones, but the map effectively drew a boundary around the community they were participating in.

While we were fostering some kind of 'community awareness', what stood out, however, was how people did not propose any kind of community action site to support such affairs as monitoring and reducing consumption. Instead, people used the website for a subtle awareness of differences between homes. Sumit referred to it as an interaction of "*machine ecologies*," seeing how devices had different experiences in varied settings.

Appreciating the Weather Stations

All participants have been living with the Weather Stations for a period of several months and this has allowed us to see a trajectory of technology adoption and appreciation transpire. After initial excitement, participants settled into troubleshooting and experimenting that eventually gave way to a feeling of disappointment. In an early field visit Meena said, "*you have to get to know these things, you have to play with them*" but at a later field visit she commented, "*it was more interesting early on and then our interest waned…It felt like [they] didn't need us. Just our electricity.*" As participants continued to live with the devices, however, we saw a new phase of the trajectory as the stations settled into the home becoming, as more than one participant expressed it, "*part of the furniture*". Brett, for example, commented that the WT's constant whirring had changed from irritating to soothing, something he noticed now only in its absence.

A big part of the settling into a new appreciation revolved around participants using the stations, most particularly the LC, as an indicator of seasonal changes. The value then was not from a point in time but over time. Sumit recognized that in this regard the stations would appeal more to his wife's sensibilities as a gardener: "*She knows where the light hits the lawn. She thinks more in terms of long time scales…a 10 year plan for the garden or what will flower in 3 months*". Several participants noted being able to see the days getting longer based on their LC readings. Tim and Meena proposed using the TT to catch varying lengths of sunbeams through their windows. Tim commented: "*If you could record how light comes in and out of your house for a year…who wouldn't be interested in that? It would be seeing time in a different way. I've done that with painting where you feel like you are doing something different [with each iteration] but you aren't. It's like a spiral - you keep coming around.*" Catherine noted that the sun's trajectory had become aligned with a stained glass window in her home in just such a way as to send coloured light patches slowly moving across the floor of her hallway. She deployed the LC to record this.

When used over time to explore the quality of light, or currents, or (to a lesser extent) temperature, the Weather Stations came to have new interest and suggested other ways to experiment. Catherine, for instance, decided to take her LC with her on holiday as a means of exploring the quality of light closer to the equator compared to her home. The stations ultimately did not surprise people, a condition that led to initial disappointment, but for some a more subtle surprise, or at least awareness, built up over time.

Tim described this slow creep of surprise when he related how he had made an oil portrait of the LC. In painting the LC, Tim described having to study it, seeing things that might have been unnoticed and to think about it for an extended period. He likened the process as similar to what any painter does, and how the act of painting transforms the object. The painting of the LC and the LC itself went up on display together in the front window he uses as an exhibition space. After its time there, the painting moved to

a corner in the home where it sat along with other pairings of a portrait and its artifact. What was interesting here is not that Tim painted the LC. What was interesting was how he rendered it in a similar fashion to the many other curious objects in his home. Through this concentrated appreciation, the LC faded, favorably, into the background.

Relating to the Design Process
It became clear that many aspects of our participants' experience with the Weather Stations are related to their understanding of our design process and our involvement of them in it. In our recruiting material, we described the project as about "developing an awareness of the home's microclimate without directly addressing issues of energy usage or carbon footprint". People told us that they were drawn to participate based on interests in the environment, technology and design, in some combination. At the orientation event, participants were exposed to the studio's way of working and to the project in general. Participants seemed to take immediately to the idea of thinking about the home as an environment and expressing these ideas through the prompts we provided, for example writing notes to appliances, telling secrets about the home, mapping smells, or placing colorful cutouts of animals and robots in 'habitats' around their home. Some participants became more expressive than others through these exercises, but most seemed quite comfortable with exploring their home in a different way.

Our participants were, then, primed to think about the home as a curious place and readily adopted the research agenda. Sumit described himself as *"one of life's participants"*, explaining that he was constantly trying out new things. All of our participants displayed a kind of commitment to the curious as well as a commitment to the process of discovery. Several times we had participants tell us that they had not interacted with the stations as much as they wanted to, yet they continued to keep their stations operating in order to log their data if nothing else. Meena talked about how they had developed an *"allegiance to the systems"* and despite the stations not being as interactive as she would like she continued to want to work with them. Tim took a long view of the project and could imagine meeting people in a few years time who had later versions of the systems and they'd compare notes.

Several of our participants had orientations towards technology which are redolent of concerns that the studio itself has expressed. For example, there is a sense in which 'the ludic' was a topical concern for participants, not just for ourselves. We had several stories of trying to blow the WT's trees down, making a competitive game out of raising the temperature of the hook versus the eye on the TT, or alternatively flooding and depriving the LC of light. Other participants indicated playfulness through more reflective activities. Elvira commented: "*it feels like we have a ghost in the house, made visible through those weather gadgets*" and John wondered if "*perhaps the Weather Stations were listening to me.*" Hing likened the entire project to an exercise in responding to "*intruders in the home*", a sentiment similar to the one expressed by Brett when he explained the Weather Stations as "*not really*

for anything…but just about what people do with them." While we have seen Meena unhappy with the readability of the Weather Stations, she also advocated a bit of uncertainty. *"We like rules but with a bit of a wild card."*

Our participants were not innocent to the world of design, nor of the studio's work, nor did they hold back from reading design intent into the Weather Stations or offering alternative design ideas or orientations to us. We have remarked that, perhaps surprisingly given the discontents expressed over the interpretability of the data from the stations and certain forms of experimentation that were soon abandoned, people persisted with the Weather Stations, at length finding interesting behaviours in them or in comparisons made between their data and other's. We suggest that this persistence, and the favourable backgrounding of the devices that is part of it, was nurtured by participants having a sustained relationship to our design process, its topics and concerns. As Tim provocatively yet appreciatively put it, *"we have become part of a crazy club with no meaning"*.

DISCUSSION
As with most investigations that pursue research through design, our work on the Weather Stations has given rise to an abundance of issues, advances, lessons and speculative conclusions over its course. These range from new perspectives on issues of the environment, to the design of a patentable swivel joint, to new tactics for arranging and maintaining batch deployments, to an appreciation of the difficulties in mapping light sensor data to appropriate colours on an LCD screen. We have touched on some of these outcomes elsewhere [19]; here we focus on participants' experiences of the Weather Stations, and reflect on their implications for environmental HCI and design for ludic engagement.

(Not) Living Up to Orienting Narratives
As described earlier, after an initial period of interest and enthusiasm most of our participants expressed disappointment in the Weather Stations. Nonetheless, for many a lingering affection for the devices persisted. To navigate our way through these somewhat paradoxical results, it is useful to recall that our intention was to disrupt or complicate simple narratives of the environmental. As it turned out, the designs complicated other narratives too.

We had explicitly warned that our designs would not directly attempt to improve environmental impacts (e.g. by promoting demand reduction) throughout our meetings with participants and particularly during deployments. Nevertheless, an *environmental narrative* implying that the devices might offer some benefit with respect to concerns about ecological issues still oriented people's criteria for the success or failure of the Weather Stations. It seemed that raising environmental issues as a context for our designs, even negatively, brought into play a host of assumptions about how designs might properly be expected to address such issues. Thus many of our participants oriented to the devices' potential utility as, e.g., draft detectors or indicators of energy waste due to excess lighting or heating. Not surprisingly, most found them wanting in this regard.

A second narrative also turned out to orient our participants' senses of the success or failure of the Weather Stations. This *ludic narrative* was implied by our previous design work, several examples of which were described to participants in orientation and deployment events and on the project website. Seeing our portfolio seemed to lead our participants to anticipate that the devices built for this project would be similar, e.g. in pacing, in giving access to large amounts of content, and in their interactional possibilities. However, the Weather Stations were slower-paced, simpler, and less interactive than previous designs, only engaging people for short periods of time rather than for extended sessions. While we observed people playfully engaging with the Weather Stations, these activities were not sustained in the long term, leading to a sense of disappointment about the devices.

As the deployment continued, we began to feel that the Weather Stations were failing both in terms of participants' activities with the devices and their conceptual appreciation of them. This pessimistic view was undermined, however, as we became aware that many of our participants were expressing an abiding fondness for at least some of the devices. Moreover, even though it was not uncommon for participants to tell us that they no longer engaged with the devices after a month or two, they were still adamant that they did not want to return them, but preferred for the devices to stay in their homes. They had become part of the home's 'background' and in a desirable way.

The Value of Batch Prototyping

It is doubtful that we would have discovered the modest successes of the Weather Stations, had it not been for our approach of running a relatively large-scale field trial based on the batch production of prototypes. Had we deployed prototype Weather Stations to only a single household, as we have done with previous prototypes, it seems likely we would have attended more to comments about their failure than to any evidence of lingering affection. If this is true, then not only did our multiple deployments allow us to see the range of aesthetic, utilitarian and environmental orientations taken by our participants, but to discern a form of engagement marked by its understatedness and intermittence. It was only because so many of our participants told us of their persisting – if weak – attachment to devices that otherwise seemed unsatisfactory that we took this quotidian relationship seriously.

From this perspective, it may seem that we have rediscovered the ability for large-n studies to reveal patterns in data that would be lost in the noise of smaller ones. There is undoubtedly truth in this, but we do not believe it is incompatible with our interest in varied orientations. If batch deployments allow us to aggregate data to uncover subtle trends, equally, they allow us to uncover multiple, potentially incompatible forms of engagement as well. This capability is important in assessing batch production and deployment as a methodology for research through design. This project marks the first time that we have batch produced highly finished, fully functioning computational devices for field trials with multiple participants. As we have described, this

was a costly process, both in terms of money and time. Our results, which illustrate the potential for batch production and deployment to allow both more nuanced and more varied forms of interaction to become evident, lead us to believe the approach a valuable one. In particular, it allowed us to appreciate the subtle but abiding attachment many of our participants formed to the Weather Stations.

Lingering Affection

In our interactions with participants, there appeared to be several sets of reasons for people's continued attachment to the Weather Stations. First, even though the devices were unsatisfactory with respect to the environmental or ludic narratives, it was possible to appreciate them as distinct devices with their own coherent identities. For some this was a matter of aesthetic appreciation, as indicated for instance by Tim's remarks about his painting of the Light Collector. But there were indications of more personal, affective relationships with the devices as well. Several of our participants referred to the intriguing presence the Weather Stations had in the home, as for instance, when Elvira suggested they manifested a *"a ghost in the house"*, or Sumit compared them to his enigmatic rabbits. The devices seemed to become active agents within the home, albeit in understated and easily overlooked ways.

A second source of the fondness we observed for the Weather Stations seemed to involve the way they portray the home as a self-contained ecosystem characterised by seasonal changes. For instance, Sumit described a 'eureka' moment in which thinking about the Weather Stations impelled him to perceive the home as an ecology and not a hermetically sealed box. Several participants remarked the changes of daylight revealed by the website's historical Light Collector data. Moreover, participants seemed to enjoy the way the devices inspired them to imagine new ways to work this design space. Over the course of deployment, we heard numerous suggestions for changes and redesigns. For instance, Brigitte postulated greater engagement if *'the data was translated into something entertaining. Like playing a tune or something. We have a friend who made a symphony from the rise and ebb of the Thames…'* Both directly and through implication, the Weather Stations succeeded in occasioning appreciation of the changing microclimate of the home.

Finally, a third reason participants seemed to find lasting appeal in the Weather Stations had to do with the way the devices tied them to a community of participants and incorporated them into the work of our studio. This became particularly clear when other participants' real-time and historical data were made available online. Many displayed great interest in comparing their own readings with others. In addition, they expressed fascination with seeing that others were also engaged with the devices, with speculating about other peoples' activities and orientations, and with the idea of having joined a larger group of people serving as informants for the design processes of our studio.

Sporadic Engagement

If people retained engagement with the Weather Stations, though, this was of a different character than we've seen in previous deployments. In other work we have discussed

how a 'trajectory of appreciation' for a given device can be discerned over the course of long-term field trials, as people's appreciation for and engagement with our prototypes waxes and wanes over time. For instance, in the first days of a deployment an initial excitement at receiving a new device often gives way to disappointment as its limitations become known. In our successful deployments, this downturn is followed by some recovery of enthusiasm and a leveling off of engagement at a moderate level. In unsuccessful deployments, the downturn is not reversed, or not for long, and over time engagement declines more or less completely [15]. This has led us to believe that sustained engagement with our devices is a clear, if somewhat minimal, criterion for their success.

Results of the current deployment require that we take a more nuanced view of potentially successful trajectories of appreciation, on the one hand, and what counts as engagement, on the other. What seems to have emerged for many of our participants are trajectories in which the initial downturn of enthusiasm is not clearly reversed, but engagement never completely dies away, either. Instead, while many of our participants have said things along the lines of 'I never really notice them any more', it becomes clear that they do notice them, periodically, and they do value them, occasionally – and that the occasional pleasure this brings makes the Weather Stations a valued part of the home's furnishings, much as memorabilia, knick-knacks, artworks and televisions may be ignored for long stretches of time, yet find their value in occasional moments of utility or appreciation.

Moreover, we have seen signs that participants' appreciation of the Weather Stations has evolved with time, as they have seen the devices respond to the changing seasons, and visited the historical data made available on the website. The evolution of appreciation is both intermittent and slow [c.f. 24], but not just because the devices take time to understand and reflect upon, but because their subject, the environment within and around the home, itself evolves slowly.

Enriching Environmental and Ludic HCI

Taking a ludic approach to environmental HCI ultimately leads both to new insights and questions. Participants readily adopted the spirit of using the Weather Stations for open-ended engagement and reflection, even while expressing dissatisfaction with how far the stations went in this regard. We had glimpses of participants using the stations to reflect on the home as 'not hermetically sealed', as a system influenced by seasons, and as a space where their movements and presence contributed to the collected changes – and we also had playful reflections on ghosts, secrets and night-time creatures. Although this speaks to the potential for intertwining environmental and ludic HCI, at least some of us feel, like our participants, that the stations are somewhat lacking. In moving forward, we are considering ways to address the participants' desire for more surprises, reflecting on both the sources and presentation of information. We are also exploring the critical role of framing, as discussed earlier.

With regards to sensor legibility, participants demonstrated an ease with the stations that we attribute to the tight correlation between what was sensed and how it was displayed as well as to their aesthetic quality. Even though the website added a layer of readability to the stations, the devices on their own were accessible and clear. Participants did not regard the stations with suspicion and even positioned them in very private areas of the home such as next to the bed or in the bathroom.

The directness of the displayed information, however, may have resulted in the stations being too simple to sustain interest. One speculation is that although each house had three stations, these represented three very discrete and somewhat disconnected points. Although participants moved the stations around, once they had acquired their spot, they tended to stay put offering a very constrained glimpse of the home's microclimate. This meagreness could be addressed in a number of ways, from adding more points of collection (e.g. multiple Light Collectors to depict patterns within a room or throughout the house) to playing off the single point reading more dramatically.

The question of gathering more points of information manifested as well in our approach of batch production and batch deployment. Much of our learning from this foray revolved around the organizational and technical complexity in moving from singular to multiple deployments. Unsurprisingly, the households with whom we conducted multiple field visits provided the most information, yet those we contacted less frequently reminded us of our objective to bring out multiple narratives and interpretations. In conjunction with the observation that the technical maintenance and development of batch produced systems needs to resemble more of a network without requiring a central organizing hub, so too we are working toward supporting this kind of networked reflection and expression. One looming question, then, is how to gather, make sense of and share with our community a richer multiplicity of views.

Finally, drawing participants into our design process through the research kits and the Weather Stations often produced reflections on environmental and ludic HCI that seem to represent a new twist on participatory design. This sense of collaboration became apparent to us through the many conversations with our participants, through the language they used to describe their experiences, and through their sense of loyalty to the project, including their depiction of 'a crazy club' in which they were members. It was not a collaboration in the sense of designing the stations together, nor did we set out with joint research objectives, nor did we 'sell them' on our agenda. The participants came to the project with their own agenda as we did with ours, and shared their interpretations of the experience just as we did ours. This form of participation – in which designed artefacts both elicit values and evoke ideas for new possibilities – is one we will explore further.

ACKNOWLEDGEMENTS

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