Number in Craft: Situated Numbering Practices in Do-It-Yourself Sensor Systems

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Introduction

How does the quantitative figure in craft? In many contexts, craft embeds enumerated processes. Kilns have temperatures to be monitored, knitting has knots to be counted, and chemical formulas for dyes are there to be followed or adjusted. Numbers in craft often come into play through technologies. Both digital and analog sensors (thermometers, scales, etc.) are widespread in craft practices. As Rosner’s work shows (this volume), digital technologies can even be deeply integrated in “traditional” crafts like knitting. We can now include in the diversity of craft all the self-described tinkerers who are building do-it-yourself sensor systems. These systems detect various things such as water quality, energy consumption, or the temperature of an outdoor barbeque. People who work with sensors rather than clay or textiles still engage in the same kind of bricolage and embodied knowledges as do other crafters in other places. They bring shape to things with the materials at hand, sometimes elegantly and sometimes less so. As with L. De Nicola’s contribution to this volume, sensors are not the sterile antithesis of craft, but are themselves crafted when people assemble them, alter them, and (re)situate them.

Some people who are most heavily invested in the sensors themselves, however, are interesting to examine because they bring the numerical information provided by sensors into the foreground in interesting, if problematic, ways. Because they bring numbers to the foreground, sensor projects provide a new location from which to think about number in craft. In this chapter we explore how sensor data features as a material in craft work alongside the sensors themselves. We are also interested in what it might mean to think about sensor data as itself crafted—that is, not just constructed, or socially shaped, but crafted. We are two scholars who spend most of our time thinking about computers, and we find the anthropological thinking on craft to be an important theoretical framework that helps us understand the significance of the numbers that computers create. Writing through the lens of craft forces us to pay close attention to how materials speak back to people in the face of the apparent authority of number, and the labor involved in numbers’ assembly.
Our central claim is that practices that use sensor numbers invite slippages between number as hermeneutic and number as heuristic. Number appears at particular times in particular ways, sometimes as abstract authority and sometimes as a contingent and partial indication that cries out for further situating work. Indeed, sometimes both aspects are in play at once. Sensor enthusiasts’ relationship to number’s apparent hermeneutics, with its emphasis on mental reckoning and abstraction, and its heuristics, which invite more careful connections between numbers and materials, profoundly affects the kinds of material engagements they have with the world around them. The choices made concerning numbers’ heuristics and hermeneutics shape what kind of sensor system is ultimately crafted. These uncertainties of how numbers relate to materials unfold even while the participants themselves feel quite certain of the separation of subject and object that academic theorizing of materiality likes to trouble.

To examine the craft of data, we conducted ethnography with people who build or use home energy monitoring equipment and upload the results onto Pachube. Pachube is a website that acts as an open data repository for sensor data of all kinds. It allows people to share their data feeds and create visualizations of them. Pachube and its users are tied to the larger maker movement (Platt 2009), and often the systems used to sense are not commercially made products, but hardware hacks of various kinds. In these systems, numbers are nominally what is spat out the other end of the sensor. This automaticity can make numerical output from a sensor appear to require no further engagement, as the technology has provided us with a datum that has already been subjected to an interpretation. If we just consider how sensor numbers are designed, there are significant differences between them and, say, the counting of knots as a basketweaver finds his way through the basket. Those latter numbers are heuristic steps on a pathway through movements and gestures that end in a product—the basket. They are enacted and embedded in the object itself. Sensors, on the other hand, are designed to “retrieve” number from the sensing, giving the impression that that number can stand on its own, as if all one needed to know about it was contained within the number itself. An electrical pulse, heat, or sound goes through a transducer and a set of algorithms to produce a number that can circulate separately from the phenomenon that initiated the process. This separation suggests the possibility of hermeneutic-like qualities, similar to the self-fulfilling divinations made by lie detectors and oracles (Rapport 1988). What else someone would need to interpret that number is a central problem of using sensors in practice. It is not always apparent.

Nevertheless, this appearance of hermeneutics is a socio-technical choice made by engineers who largely conceive of number as abstractions from the things they count. We could easily imagine alternative sensor designs that did enact numbers in ways more easily comparable to the weaving of baskets. Indeed, there are critical design projects that do just that. For example, Leahu (2009) uses sensors measuring the electrical resistance of skin as a heuristic for emotion, which is a commonplace in some research fields. He does this in order to demonstrate the ways in which sensor readings are not coextensive with experienced emotion. Although sensors do abstract numbers from the phenomena

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1. pronounced “patch bay,” and as of mid 2012 was renamed Cosm.
2. A “hack” in this context is not defined as a breach of computer security system, but a clever, non-standard way of working around a problem using available materials. Using duct tape to hold wires in place is a hack.
they sense, these phenomena are often not identical to the real phenomena of interest. Yet, by virtue of the “reading” being abstracted from the measuring event, the door has been opened for a slippage from a modest heuristic to a more ambitious hermeneutic. The threads that would otherwise situate it as partial knowledge have been cut by the design choices made.

Actual practice, of course, complicates the intended design. For the people we worked with, to describe sensors as simply spitting out a number in the way their designers intended in no way does justice to what is going on. In fact, the craft of making sensors actually useful for something far more resembles the numbers woven into a basket than sensor manufacturers may care to admit. For those of us who are concerned about the fetishization of number in contemporary life, we might take heart to learn that in this ethnography, the numbers held to be stand-alone “facts” establish less social currency than their more modest, more contingent counterparts. Those “facts” require feeling one’s way around the broader context to become meaningful. As we describe below, incremental “feeling your way around” requires careful attention and interaction between sensor readings, the sensors themselves, and the knowledge practices involved in hacking together a system. Such “feeling your way around” is not always successful. Numbers are difficult materials to work with not because people “can’t do math” (in our study, many participants had an engineering background) but because they do not offer themselves up for use in quite the same way as circuitboards and pieces of software code. They offer more contingencies than certainties.

In the section that follows, we will address the literature from both studies of craft and studies of technology (an unfortunate distinction with an even more unfortunate gender politics (see Nafus 2012)). We tie these literatures together through a third—ethnomathematics. We take as our starting point Ingold’s focus on incremental feeling one’s way through the world, and reflect on how both numbers and digital technologies do or do not challenge this incrementalist approach to craft. We then offer three ethnographic vignettes of home energy monitoring systems that show the uneasy heuristic/hermeneutic relationship. Lastly, we discuss the wider cultural frameworks and practices that largely expect numbers to perform hermeneutically, and how this inflects the craft of number.

Getting a Feel for Numbers

Ingold (Ingold 2010; Hallam and Ingold 2007) offers us a way of thinking about craft that is not moored to a distinct set of artifacts against which to contrast “art” or “technology,” but as a wider theorization of how we might think about human engagements in the material world. Drawing on Flusser (1999), Ingold contrasts craft with “design.” Design, he argues, is caught up in procedures of modernist plan-making where it is assumed that one can lay out a design and then simply implement it as planned, as if implementation were a matter of brute labor. Craft, on the other hand, is a perspective that acknowledges that building and making constitute a material way of knowing, learning and acting within the world. In other work, Ingold (2004) takes this notion further. He asks about just how much of a difference it would make to not experience the world with our hands and eyes but our feet. What would it be to more closely attend to the pathways that our feet take us along, the materials underfoot, etc?.
This difference highlights how our hands and eyes really do situate us in the material world. They are not simply to be dispensed with through sheer mental reckoning, or easily swapped for feet. In yet other work with Anusas (Anusas et al. 2010) the question centers on how we might subvert environmental design in ways that would make it more craft-like. What happens if we dispense with design as pre-planning through so quantitative scalpels, “managing” CO2 emissions with targets, green building metrics, and built buildings for actual living? Noting that these measures are abstractions that have little to do with life as it is lived, these authors call for building environments for life rather than measurements.

By defining design and craft in these ways, Ingold’s work intriguingly spans everything from basketry to environmental policymaking and assumes a point of view that seeks redemption in the immediacies of the material as a way of keeping at bay the inhumanities wielded in the name of modernist abstraction. The violence done by such abstractions also has been resoundingly critiqued elsewhere (Strathern 2000; Scott 1998; Ferguson 1990). While we find Ingold’s attention to the incremental responses to materials useful, the contrast he draws with “abstractions,” and the ease with which quantitative representations fill that slot, is an ease that requires caution. While digital technologies and manufactured artifacts are designed for a notion of modernity he finds objectionable, they also do not preclude the incremental back and forth between materials and persons so central to his work. Indeed, communities of “makers”—people who take pleasure in various modes of do-it-yourself production—have proliferated across North America, Europe and Japan. The home energy monitoring enthusiasts we worked with largely see themselves as part of this proliferation. Makers, like their “back to the land” parents and grandparents, seek to “return” to an earlier way of life yet do so within today’s digitally infused material culture. In Ingoldian ways, they have elevated direct material engagement with artifacts as a specific kind of knowledge making practice.

The maker movement resists the notion that mass manufacture might have the last word on the sorts of objects we must live with (Minahan and Cox 2007; Williams, Gibb, and Weekly 2012). Maker communities took matters into their own hands long before David Graeber (2012) complained that technology has yet to deliver our jet packs as promised. Graeber argues that through the privatization and bureaucratization of technical research, technology delivered far more underwhelming, docility-inducing technologies of screen and image. This is a fair complaint, but also is only part of the story. For example, Maker Faires, gatherings of makers that celebrate the work of many makers, represent no such failure of imagination. DIY concept cars, robot petting zoos, and a firebreathing flock of umbrellas built by a women’s welding cooperative were all featured in the San Mateo “flagship” Maker Faire in 2012. Scholars like Ratto (2011) have further turned to material making as a site of critical practice; that is, not just a critique of the limits of capitalist production but also as a way for scholars to call into question the dominance of discursive knowledge, rather than material and embodied knowledge. In Ratto’s critical making studios, people do not just think with their hands, they “write” with them. The objects they make are a site in which the process of critique takes place, where the materials resist and speak back to the maker.

Asking about how sensor measurements might be crafted offers a different perspective on Ingold’s presumption that the quantitative is synonymous with abstractions and the modernist gaze, as if it were
only clay or wire that could present an immediate material experience. Ethnomathematics research (Verran 2001; Guyer 2004; Eglash 1999, Lave 1988 Pryke 2010) shows clearly just how immediate and material people’s experiences with numbers are. That is, there may or may not be a “pure” mathematics awaiting our comprehension in some Platonic plane, but what matters about math is always in the doing. Prices in a grocery store, lengths of rope, and the near tactile surfaces of financial market volatility visualizations provide the materials that “clot” numbers together (Verran 2001) into both meaning and practice. This is what makes it possible to feel one’s way through a math problem in a grocery store largely in the same way as feeling your way through a clay pot. There are cues, gestures, and components of habitus that make them both numerical and bodily at the same time. Indeed, Pryke’s (2010) work on how financial traders use financial data visualizations as a prosthetic to gain a feel for the market, and respond with skilled anticipation is hugely similar to O’Connor’s (2005) work on glassblowing. For O’Connor, glassblowing tools become, over time, a prosthetic that allows her to anticipate her next move in blowing the glass. Numbers are not always or inevitably the quantitative scalpel of abstract precision wielded from on high. Instead, we have to be more careful about what kind of number it is meant to be and how it is being used in practice.

The scholarship on information technologies has grappled with analogous issues. In the 1990s and 2000s technology studies spent much time concerned with the question of whether the digital is “real” or a “virtual” simulacrum of that reality (Woolgar 2002; Wellman REF, Turkle REF). In our case, sensors have material form; they attach to things, they emit waves of various kinds, they contain electronic components, etc. They transform physical substance into numbers, which, however physical the electronic pulses are that create numbers on the computer screen, is nonetheless a significant transformation. To borrow from Boellstorff (2010), these transformations into numerical form create a virtual experience only in the sense that culture has always been a “virtual” experience. Culture is as real as metal or wood, but also very different from them. These differences do not make culture a simulacrum of life, or an abstraction from life. Numbers too are not especially marked as “abstractions from” some other, more real experience. Although not exceptional, like any other ethnographic object, they also have to be taken on their own terms (Boelstorff 2010). For our project, this means we that can ethnographically trace the transformations that sensors perform, and take those transformations seriously, without resorting to philosophizing about the need to overcome subject/object dualisms to locate the “realness” of numbers. Methodologically, this requires attention to the practices of crafting number and refraining from claiming new theories of materiality. In Miller’s words, “there are plenty of other people who claim to have invented the wheel that rescues anthropology from the simplistic duality of subjects and objects” (Miller 2005: 10).

What makes sensors interesting for thinking about number in craft is that, at first glance, sensors appear to make the invisible visible. Sensors render phenomenon as various as location, motion, temperature, electricity, gasses, radiation, and small particles visible in some ways, but not others. Through digitization these phenomena, which we otherwise might experience as heat (temperature) or a shock (electricity) or confusion as we head the wrong way down the highway (location), can be reframed and reconceived. What is at stake, then, is not just the way in which sensors force their users to grapple with the mathematical, but also, how we think about the material experience of tinkering with that
which we cannot see. This is not a case where electricity, temperature, etc. can be assumed away as epiphenomenal properties of the material we craft. The touchable, visual aspects of objects are not the only things manipulated. In these ways, sensor projects may render manipulable the material world differently than other forms of craft.

However, it would also be untrue to say that sensors fully make these phenomena visible. Indeed, an interesting tension in our fieldwork is that people say on the one hand that they can “really see” their electricity through sensing systems, and at the same time they know full well that they are not “seeing” electricity in some unadulterated, unmediated way. They know they are looking at a number. While sensors often take numerical form, they do not have to: a dirty camera lens can serve as a pollution sensor. The challenge we face is, on the one hand, to not flatten everything and anything into materials of equal kinds, such that we find craft everywhere we choose to look, and on the other hand to steer clear of fetishizing number and measurement as abstract operators on a higher ontological plane. If we are to preserve the Ingoldian attention to the incremental feeling-your-way-through, we must look for the numeric, material, and social “clots” where they happen as we trace the transformations.

**Sensor Systems**

In this section we begin by ethnographically describing three home energy monitoring systems which in some senses are illuminating outliers. We then discuss how the treatment of number in these examples differs from the bulk of the sensor systems we examined.

**The Heat Loss Meter**

There is a fairly well-known home improvement scam that involves salesmen using a “heat-loss meter.” A salesperson comes to the home and offers to do a heat loss assessment using their measuring instrument. When they get to the home, they remove a handheld meter and walk around a person’s living space. The homeowner is also allowed to wield the instrument. What the meters invariably show is that windows are a primary vector for heat loss and the sensor owner offers to sell new windows, which they claim will pay for themselves quickly. The scam is based on the meter that they use, which itself ensures that windows will always be the primary culprit. They use a photographic light meter.

The scam works because there is a large gap between what people think might be involved in home energy efficiency and how complicated it actually is. Home heating is something that was infrastructuralized well before living memory for people in post-industrial countries. The largely unchallenged ubiquity of central heat systems has meant that they only become visible upon breakdown (Bowker and Star 1999). They have become black boxed (Latour 1987). In this case, the breakdown in question is not an issue of lack of a power source but a realization of the damage and cost of its overconsumption. Precisely because infrastructures tend to become visible only upon breakdown, their operations present themselves to most people as ignorable technicalities. Few of us really have any sensibility about what 77 kilowatt hours actually means. Combined with a cultural politics that privileges the visible, particularly when that visualization has been rendered numerically (see Dumit
2004), a certain level of convincingness emerges. This is the case not just for seemingly unsophisticated victims of scams, but is a wider cultural problematic. Dumit’s work shows how brain scan imaging creates an overconfidence that one can “really see” what is happening in the brain. What viewers are “really seeing” depends just as much on choices of color contrast and the circumstances of the scan than any underlying pathology.

Perhaps more importantly the scam deliberately muddles different modalities of numbers. It creates confusion between different kinds of proxies to deliver a suspect authoritative measurement. Windows are not an unreasonable proxy for likely heat loss. Light is not heat, although it may in fact indicate a heat source or loss point. In fact there are multiple modes of heat gain and loss, all of which may or may not translate into overall power consumption. It is too easy to allow ourselves to believe that a single device can perform a deep reading of the heat loss profiles of various areas within their home. Sensors, no matter what they do, are only ever a means of building a reasonable approximation, a good guess as to what they want to know. In Peircean terms (Peirce 1932) sensors are indexical, in that they point to a phenomenon but never are the phenomenon itself, leaving the door open to a range of complicating factors. In fact, what could be indicated are often just related phenomena. They are co-occurrences, not necessarily the root cause of what one is trying to detect (a distinction that Leahu’s work cleverly brings out). If we look at sensor readings in these terms, the are heuristic rather than hermeneutic devices. They deliver parts for some method of proceeding and do not necessarily contain all the parts for thorough interpretation. In practice, however, the two are easily muddled. This is not a failure of “ordinary people” to be “more scientific.” Instead, certain aspects of material culture and socio-technical knowledge make it difficult to maintain a regard for these two modalities as separate.

“You get geeky quickly when you live on a boat”

Martin is a graduate student in his late 20s who lives on a canal boat in North London. Martin lives this way out of concern for the environment. The boat creates an awareness of energy consumption and inspires the sorts of energy saving practices that many of our home energy sensor enthusiasts strive for. Boats are necessarily off the electricity grid, and as a result, in Martin’s words, “you get geeky quickly when you live on a boat.” There are four options for energy—petrol (gasoline), diesel, solar and wind. Martin uses all but wind, for the reason that wind is noisy and incompatible with complaining neighbors. All three sources feed into a battery bank, but the battery bank in turn is a bit of a mystery both to him and his community. These mysteries require developing practices and routines which other boaters have established and have willingly shared with Martin.

While it is possible to take voltage readings, the practical number to know is amp-hours, which is a unit of charge. This is because voltage only tells the potential energy released from the battery per unit charge. Although voltage does drop precipitously immediately before a full discharge of the battery; its measurement is more or less constant up until it nears the point of full discharge. For people concerned about how much energy is left in a battery, and therefore how much longer it will last, amp-hour is the more significant measurement. To measure amp-hours requires prohibitively expensive
equipment. In addition, amp-hours are dependent on temperature, so anything but constant amperage measurement would only yield an estimate, a heuristic not much better than simply knowing how much energy has been drawn since it had a full charge, another heuristic for understanding how much energy is left.

The mysteries of the battery bank as understood within this community include the problem that the battery is said to perform best when neither full nor empty. Ideally it should only be between 50% and 80% of capacity. Rules of thumb have emerged to figure out how to maintain this ideal: when to top up the battery, and with what. Diesel might be miles away or nearby, the day might be cloudy and inhibit solar production, etc. Or, on the consumption side, when a laptop is about to die and there is an impending deadline, Martin knows he has to turn out the lights to crank out that last bit of work.

Similarly, his heating system uses a mix of wood and coal: visible materials whose consumption he must carefully calibrate so as not to run out at the wrong time. He must not be so far from a source of either that it would be difficult to access more, but also must not load down his boat with a large amounts of heavy heating fuel that would make it expensive to move the boat with his diesel engine.

Within the community of canal boat dwellers, there is an extensive system of shaming for consuming the wrong kind of energy. He says in full knowledge of the irony that “the community has a lot of hippie anarchists who police consumption.” Martin emphasized in our interview how living in this way meant he became attuned to the materiality of energy. His thinking centers on the limitations of resources, and the interdependence of technical systems, that would not be possible if the energy was just “on.” Yet at the same time he also “doesn’t want to fetishize this.” His pleasure is one that comes from a material practice, but he made clear to us that data is compatible with getting a bodily feel for what is going on. Indeed, the ability to measure amp-hours he believes would be useful, if potentially inaccurate and expensive. What he does disapprove of is reducing energy use to cheap sloganeering (“Turn one light off if you turn another on”). These are not rules of thumb but oversimplifications, and what he is doing is deliberately complicating the banalities of such discourses. His concern is that digitized forms of energy monitoring, as currently designed, invite oversimplifications that can be intrusive and manipulative in the wrong hands.

Far from a cheap rejection of the modern, boat living gives Martin a reason to care about the difference between amps and voltage, and the skill to make good use of it. The data is embedded in the doing: computer batteries at 10% become an urgent indication to turn off all the lights if boat batteries are also at 10%. He finds the constraints of boat life to be a material frame within which to establish a more nuanced practice as well as develop a deeper awareness. He uses the word pleasure to describe this engagement, and at the same time rejects any romanticization of off-grid living as some nostalgia for a premodern existence that never was. Such nostalgia he ascribes to his “hippie anarchist” neighbors. Rather, his marginal position in relation to the grid gives him a different perspective on it and way of engaging with it.

“They just wanted to hear about the sensors and I wanted to talk about the system”
Martin is in some ways not that different from Bob, who is an enthusiastic maker of home energy monitoring systems and Pachube user in Berkeley, California. Bob’s practice is equally incremental, if far more reliant on sensors and numbering systems. Bob articulated a very clear path from the generic to the increasingly granular; his practice too was about making material resources more complex, not simplified. He started out using a Kill-A-Watt, an electricity monitor that clamps onto the main electrical feed to the house and gives the reader an indication of overall electricity usage. As an engineer, Bob already understood that there was no one-for-one relationship between an overall house usage number and turning off the television set. “It just doesn’t work like that,” he explained. Yet despite all his training as an engineer, how it did work was as mysterious to him as batteries were to Martin. For this, Bob turned to sensors. He installed a temperature sensor (that is, a thermometer that connected to a computer) in each room in an effort to understand how the airflow in his house was working. This allowed him to tweak the venting system to improve efficiency. Each additional sensor was for him a guidance system, a navigation tool to understand which vent he should look into or draft he should try to stop next. As in the incremental material engagements with the world that Ingold celebrates, he knew there was no totalizing system, no once and for all optimal house configuration.

Bob both did and did not intellectualize this mystery. He saw home energy monitoring as a matter of (self)education and awareness, and in this sense he saw it as an intellectualizing project. Yet because he had a strong sense of sensors’ connection with the indexical, it remained tightly coupled with practice. Sensors were his prosthesis; he made no attempt at creating some grand algorithm of his TV set as a function of overall energy consumption, for example. The house was the frame for the practice in the way that Martin’s boat was his frame, but here that frame was held together with numbers. Bob’s reliance on numbers did not take the form of a once and for all model that could say or do anything outside the construction of the system itself. Bob is just as disinterested in making trite claims about overall energy saved as Martin is.

In this, both Bob and Martin are unusual; it requires a particular kind of motivation to engage in such consuming practices. Like Martin, this frame held together by numbers was a frame that Bob was unwilling to share with power companies. Bob was squarely against smart meters which were, at the time of interview, a source of political contestation. His view was that smart meters were in no way about helping people save energy, they were about helping power companies manage power loads across a grid. He was suspicious of any “discounts” given during off-peak hours as a way to soft-pedal rate increases during on-peak hours. Time-shifting consumption did nothing to lower overall consumption, so as far as Bob was concerned smart meters were a thorough greenwash. He had further concerns that such technology can detect the power signatures of appliances. Such signatures are different not just between refrigerators and microwaves but different between brands. This would create an enormous, easily monetizable database to exploit. These suspicions are connected to Bob’s broader commitments to numbers serving as a heuristic for people to develop their own frames. Bob believes that home energy monitoring should instead truly educate people so that they too know what 77 kilowatt hours means, so they can feel it as viscerally as people feel 56°F. The power companies had no incentives or capacities to do this, and were bandying about “77 kilowatt hours” as a kind of shallow
hermeneutic: a way of signifying the “goodness” of energy saving while discouraging ordinary people from looking under the hood at what is really happening.

Figure 1. DIY home energy monitoring hub.

Significantly, this incrementalist practice of feeling his way through in response to numbers only emerged in the middle of our three hour interview. When we first sat down to talk, he wanted to show us the system hub that he had built and recently showed at Maker Faire. He talked at great length about how he had sourced the various components, what each of them did, the methods of establishing connectivity with the sensors strategically arranged around his house, etc.. One could easily get the impression this had nothing to do with energy saving at all. His story did not start out with a desire to reduce an electricity bill or an articulation of his environmental concerns, but with the above equipment, and his longstanding love of tinkering. One explanation could be that the week before he had been called upon to exhibit this equipment at Maker Faire, and so had a well-rehearsed shtick in his back pocket he was ready to perform. This in and of itself was interesting in as much as it is skillful display of repurposed materials, not numbers, that grant participants at Maker Faire social capital.

In turn Bob was disappointed by Maker Faire attendee’s questions: “They just wanted to know about the sensors.” Having an incrementalist sensibility, Bob knew that throwing a bunch of sensors together and stirring the pot was not how things worked. They were not instantaneously additive but additive only through craft, which for him took the form of systems integration: resolving the technical problem of how to appropriate off-the-shelf sensors, and get them to interoperate such that he could upload data onto the web. Fair attendees wanted to instantly imagine easy, nearly magical indicators in the same way that mass manufactured home energy monitors represent matters as a single, supposedly-tell-all number. (See Figure 2 as an example). Bob was removing the black box from the wider practice,
not just the box that contained his systems integration, and this proved disappointingly difficult to share.

Figure 2. Number as hermeneutic.

Useless Numbers

Bob was an exception in many ways. The bulk of our research suggested that most of the effort and interest happens at the hardware level. Indeed Bob himself is a hardware enthusiast and was disappointed that his audience wanted to know about “the sensors,” since he had built the hub and not the sensors themselves. However, talk of “the sensors” was doing more than querying how the sensors acted physically. For Maker Faire attendees they also acted as a proxy for a self-evident number, a number that would allow its reader to see the world differently, perhaps make it more legible, directly through the properties of the sensors themselves. Yet numbers designed to do this more often than not fail at their task.

The off-the-shelf sensing systems used by many of home energy monitoring people with whom we spoke (a component of one is pictured in Figure 2) can be used to exemplify this problem. Within our interviews, both hardware hackers and non-hardware hackers pointed to their dissatisfaction with systems that reported “just a number.” Users only saw the number when they were looking at the device. Some devices provided no record of themselves, and those that did provided no way of manipulating the data. There was no easy enough way of associating it with other data to make comparisons to understand what might be behind that number. Who knows whether it is a “good number” to have? In one person’s words: “So I can see the proverbial spike when the tea kettle\(^3\) goes

\(^3\) In UK households, kettles are typically electric and plug into the wall. They are not designed to be heated on a stove.
off, but that still doesn’t help me.” This is very different from Martin’s boat, where energy consumption or production with one device is readily compared to the next. Without successful comparison, the whole system fails, the boat doesn’t run and Martin is cold. Bob, through painstaking incremental development of his system that used numbers as heuristics to constantly reconfigure that system, did not suffer the uselessness of numbers. Both Martin and Bob had the right material configurations to practice within a hermeneutic frame broader than a single sensor number, whether that frame was a boat or an assemblage of multiple numbers and drafts. Off-the-shelf device customers tended not to. In those devices, the single sensor and its reading was intended as hermeneutic.

For people other than Bob and Martin, this difficulty manifested itself in a few ways. Some participants had been involved in hacking wireless broadband router sold as part of broadband connectivity service by a local Internet service provider (ISP). The hack enabled them to download their data from Pachube more easily. This hack was similar to the system that Bob had shown us. Yet their thinking behind this sensor integration effort was for the most part very different from Bob’s. For many, the numbers generated were a display of the existence of the system, not necessarily an investigatory practice. For example, some had developed or used mobile phone apps to display the graph of single digit home energy consumption remotely. There was some marginal utility in this; one person recalled being on holiday during a particularly cold winter and the power had gone out. He could see it on his phone and had a neighbor check for burst pipes. Another person turned to home energy monitoring because the electricity company had gouged him for electricity usage that he believed to be physically impossible for one house to use. A home energy monitoring system would enable him to prove his case should he be gouged again. Yet he too acknowledged that entering into a protracted fight with a large corporation takes more than just data and it might not be a fight he was prepared to enter again. More frequently, however, the numbers were shared with people who did not have home energy monitoring systems as an indication of what the systems can do. They were also shared with other enthusiasts as a way of discussing what kind of set up the enthusiast had. Some people were enthusiasts spreading the word, but for a few in the business of “greening” homes this practice was a sales tool.

Some of these people thought about those numbers as not “yet” useful. They had not abandoned them, but there was a notion that more had to be done. This “more” presented itself as more hardware. Some had added ways of measuring heating oil consumption or gas. Others wondered about doing more measurement themselves. Such a “more” would produce more data, but the sensibility was not necessarily about the data collection per se. In fact “more data” could easily be found on the web. Our collaborator Marc Bohlen, a media studies scholar at SUNY Buffalo, had reworked the home energy data our interviewees had uploaded onto Pachube into different kinds of visualizations not available on Pachube. In the process of doing so, Marc had pulled publicly available weather data to compare with

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4 Technologies before Current Cost (e.g., WattsOn) did not make it easy to upload data onto the Internet. Current Cost does afford that possibility but, for this group, the pre-made connection back to the Current Cost monitor (in Fig 4) was not sufficiently efficient. However, “efficiency” may have been simply an excuse to build more hardware.
the thermostat data that our interviewees had uploaded. The thinking was that perhaps the issue was not one of whether the thermostat was “high” or “low,” where high represents consumptive behavior and low ecologically-minded restraint. Perhaps looking at it relative to outdoor temperature, and next to a graph of overall electricity consumption along the same time series, might give an indication of how hard the system was working. Although this data was readily available on the web, and it is not a large intellectual leap to note that energy consumption rises relative to weather as well as how high the indoor temperature is maintained, this was not something pursued by any of the people with whom we spoke. It seemed to them a good idea, an idea both elegant and obvious once presented. However, it was not an idea that had arisen in the process of deploying and using their sensor systems. What was obvious, instead, was that more sensors would be needed.

What is the difference between Bob using temperature differences between rooms to rework his HVAC systems and people for whom monitoring the electricity mains raised the question of more sensors on other forms of energy consumption like oil and gas? In part the instinct is the same. They are both using numbers as heuristics to reveal additional unknowns. There is an implicit acknowledgement that total electricity use is not in fact the same thing as “efficiency” or “greenness.” But there is a difference inasmuch as Bob was not attempting to arrive at a grand number inclusive of overall energy consumption. Conversely, the impulse to combine overall electricity with overall oil or gas consumption, particularly in light of the practice of using these readings to display the existence of the system rather than adjust the qualities of the house, suggests that their heuristics are working in the service of a kind of totalization. Even though there was widespread sentiment that total electricity consumption was, on its own, a useless number, here the impulse is to add, not situate. From plots of total electricity use over time, (Figure 4), one could in fact infer a rough breakdown of some appliances in use. Interviewees could tell us from graphs when the kettle went on, the cycles of electricity use associated with their refrigerator, but not all. With improved sensor technology we might expect the legibility of these electricity signatures to improve. Nevertheless, such breakdowns were being read as a decomposition of a total figure, not necessarily numbers in action, as Bob’s numbers were. Few people we spoke with had actually gone out and bought a more efficient refrigerator or tweaked their HVAC system. The heuristics used in the service of totalizing calculation were not used as numbers in action. There were other numbers that were not created that were necessary to make judgments (for example, a comparison between energy spikes generated by my refrigerator versus yours).
There was a nascent sense amongst Pachube users that numbers ought to be numbers in action, even if they were using them to perform the existence of an otherwise lovingly crafted hardware hack. Our interviewees liked using Pachube because it provides data storage and visualization tools, both of which made their sensor readings more “live” than the box on a wall as in Figure 2. Nevertheless, they were not turning to Pachube to make comparisons with other home energy monitoring systems, or to find other datasets. In part this has to do with the material constraints Pachube posed. The website design at the time of interview made comparisons between data feeds too difficult even for this group. There were interfaces that allowed those skilled in software coding to do so, but even for skilled coders this took a good deal of time. Comparisons with others was not embedded within the visualization tools on offer.

The inclination to turn to yet more hardware as opposed to more data that would have helped achieve the stated goal revealed certain dispositions. Indeed, the online information sharing that did occur traded more in hardware setup—how to take apart the router, where to source the sensors, etc.—than the procedures of sense making with the numbers the system produced. While there is a growing
professional field of information visualization, visualization techniques also did not circulate readily. The keen curiosity displayed in learning how to repurpose a broadband router seemed elusive when it came to questions of what the data was actually saying. Questions like “could it be that your energy consumption is high/low relative to others because you have an old/new house?” were answered with a degree of flatness, perhaps because the answer to this question would have required bringing in data that they were in no position to identify and access. Our interviewees spent the time to build systems to collect data but were less inclined to spend time establishing ways to interpret it. This suggests that sensor readings were in a kind of a limbo between a heuristic and a hermeneutic, where the hermeneutic qualities were proving unsatisfying and the heuristic qualities were not evident as materials with which one might feel their way through iterations on the built system and associated practices. As Bob’s experience shows, there does not need to be a lot of data to be satisfying, but the disappointments of hermeneutic readings of data did suggest that more was likely to be necessary.

Conclusion

Returning to our original question, then, of how it is possible to think about data itself as crafted, we can suggest a few approaches. The quantitative data collected by makers in this ethnography is not the scalpel of inhuman precision Ingold fears—although some sensor enthusiasts would perhaps wish it were! Bob’s sensor system was built with counts of temperature as much as with circuitboards. It made the invisible phenomenon of airflow visible enough, through the proxy of temperature, so that he could redirect it. This practice could be thought of as one of Verran’s “clots.” Yet at the same time there was surprisingly little crafting of the data that was uploaded onto Pachube, even though energy monitoring systems in principle were there to help people make sense of their energy consumption. The monitoring system would be considered a failure if it did not assemble a number or if what was crafted was a wildly inconceivable number. There was a deliberate production of a certain kind of number over others, even if the time and effort spent creating it bears little relationship to the time spent looking at it, contemplating it, or using it.

However, there was nevertheless an all-too-easy presumption that measurement acts as a form of totalization. We do not mean that people were literally presuming that numbers were an aggregation of many things, but in the sense that they often treated sensor readings as if they were the total of what is both knowable and worth knowing. We could choose to argue that people were mistaking heuristic for hermeneutic, where, as any good scientist knows, numbers are only mere assistants to a hermeneutic analysis, not to be taken at face value. Such language would introduce a science-izing worldview that is not necessarily appropriate for our participants. Few set out to “prove” some property of electricity or conduct some complete analysis. At the same time, numbers increasingly do serve as totalizations—hermeneutics unto themselves—in multiple spheres of life. They have been enacted and performed in totalizing schemes such as agrarian reform (Scott 1998), growing audit cultures (Strathern 2001). The performative aspects of number have become dominant in economics in the extreme (Callon 1998). The issue is not one of lay people doing “bad science.” Rather, these larger trajectories overwhelm a more modest sense of numbers as “mere” heuristic indexicals.
In this wider context it cannot be coincidence that sensor numbers struggle to contain the ambitions people have for them. This context encourages people to see the production of numbers as the production of an answer which already contains within it all the necessary components to both understand and act. Ingold, Strathern, and Scott are of course right to complain about the ways that numbers-as-totalizations render marginal or invisible certain practices and even whole social groups not deemed countable. Yet, the dominance of totalizing numbers is also incredibly difficult to change even for people who do not face that kind of marginalization, and who arguably should “know better” as engineers. Those who “know better” are constrained by the way in which the wider social prevalence of totalizing numbers gives the impression that the practices around sensing are complete upon producing a reading. This impression may be exacerbated by the design of the sensor systems themselves, which do not situate these data, and might make it seem as if the numbers are capable of standing on their own. The people enthusiastic about the hardware hacks but bored by the numbers they produce readily admit there was very little “practical” about building elaborate sensor hubs. Both the people who rejected home energy monitoring devices generally, and those more enthusiastic faced the problem of making the numbers useful, or else establishing other non-utilitarian purposes for it.

In Pryke’s account of financial visualizations mentioned earlier, those data were every bit the same kind of prosthetic described in O’Connor’s account of embodied knowledge in glassblowing. In sensors, we have numbers that sometimes serve this role, and enabled people like Bob to tinker with that which they could not see directly. Where sensor enthusiasts attended to the craft of number, they created for themselves a fuller “basket”—whether a boat or a house—to weave through in embodied ways. When they attended to the craft of off-the-shelf hardware systems that did not situate numbers, not only did the number appear as if it were a hermeneutic unto itself, but it also failed. It became a boring number, not communicating any information at all. In the cultural and gender politics that would situate craft as the material culture of the subaltern, incapable of god-trickery and marked by the bodies of those who do it, and a politics that would situate science and engineering as a privileged, unmarked universal, we should remember how numbers fall into disservice. We can agree that the craft of everyday bench science is rife with situated, cautious numbers and still see how, in popular accounts of science, numbers become unmoored from their material context. They circulate as if they were facts not in need of contextualization, and this gives scientific knowledge its privilege. These notions of numbers’ seeming always-present-answers also gives sensor projects their privileged cultural position. Sensor projects are more commonly discussed as a form of citizen science rather than a form of craft, as if science were entirely distinguishable from art. Yet it is precisely this urge to make numbers mean more than they can, and the frustratingly elusive difference between 77 kilowatt hours and “greenness,” that means the numbers generated as a consequence of this privilege are so rarely used in useful ways.
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