Infrastructures and Their Discontents: Implications for Ubicomp

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Abstract. Infrastructures (persistent socio-technical systems over which services are delivered) are normally taken for granted by their users, but are powerful forces of constraint and enablement with implications for the design, use, and adoption of ubiquitous computing. To approach the study of infrastructure from an ethnographic perspective, we conducted an exploratory field study of people for whom infrastructure had become visible due to some form of active engagement (rejecting, augmenting, or caretaking). From considering together individuals as disparate as homeschoolers, gated community dwellers, and voluntary simplicity advocates, a number of challenges and opportunities for ubicomp emerged in terms of appropriation, empowerment, and reflection.

1 Introduction

Ubiquitous computing (ubicomp) is a vision of infrastructure. Indeed, it is a vision of multiple infrastructures – some new, some existing; some virtual, some physical; some technical, some social – all coming together in a seamless way [1]. Much attention in the research community has been paid to the plethora of technical and socio-technical challenges set forth by this vision, from techniques for sensing and encoding context, to requirements for new user interfaces and user interaction paradigms, to the need for new kinds of devices, middleware systems, and architectures [2, 3].

In this paper we call attention to the notion of infrastructure itself, particularly the notion of ubiquitous infrastructure, and argue for the utility of an ethnographic approach to the study of infrastructure. By an ethnographic approach, we mean one which seeks to understand how an infrastructure is perceived and conceived, emotionally understood, and interacted with from the first-person perspective of its users. We sketch an initial exploratory study of "infrastructure discontents" by way of illustration, and discuss its potential implications for the design and deployment of ubicomp systems, anticipating new sources of value, concern, and potential backlash.

Merriam-Webster defines infrastructure as the underlying foundation or basic framework of a system. They are often hidden and, to adopt Tolmie et al.'s [4] terminology, unremarkable aspects of daily life, posing obvious challenges for empirical observation and study. The problem of drawing out and making visible for analysis important but taken-for-granted structures of environments and routines is pervasive in qualitative field research. In response, many approaches have been developed, including analysis tools like pause-and-review video [5] or maps that aggregate events over time [6], to call attention to easily overlooked features; filtering schemes that

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wait for breakdowns or critical incidents [7], abnormal times when hidden phenomena surface, apparent to all; critical readings of "master narratives" latent in the infrastructure itself [8]; or studies of (or by) "outsiders" such as novices (see [9]) or members of different cultures, for whom familiarity has not yet backgrounded the issues of interest.

The approach we took is closest to this last one, of finding special populations for whom one or more infrastructures would be matters of daily effort and engagement instead of hidden forces. But rather than looking at novices or other cultures, we took as a starting point a current stereotype in our own culture: the rugged backcountry individualist living "off the grid." "Grid" here refers most clearly to the public electrical grid, which the off-the-gridder either does without or replaces with self-generation. (It may also reference the typical grid pattern of urban streets imposed by city planners, which the off-the-gridder has escaped by moving beyond the reach of streets, and indeed probably pavement, not to mention zoning regulations.) This schematization of "grid" has an interesting resonance with visions of ubiquitous computing, in which network connectivity becomes just another utility [10, p. 63] (and, in some versions, enforcement of information flow policies becomes integral to the network).

The notion of living off the grid – independently, freely, without being tied to, trusting of, or complicit in the benefits, costs, and responsibilities of mainstream, "modern" life – has a certain subversive appeal. Indeed, that is part of the point, the intentionality behind this lifestyle: to critique the mainstream culture and demonstrate alternatives. There is a surely fascinating and complex reality behind this stereotype, well worthy of research. However, we chose not to narrow our focus at the start to this highly politicized, self-conscious, and perhaps intentionally self-marginalized domain, but to treat it as a provocative jumping off point. We generalized from this initial notion along a number of dimensions. Expanding from the idea of a single "grid," we sought to investigate multiple infrastructures, of various scales and compositions, ranging from public eduction and physical security, to electricity and internet Expanding from a binary, static, all-or-nothing idea of being either "on" or "off," we wanted to consider a range of relationships people might have to infrastructures, how these change over time, and what they are moving *towards* not just what they are reacting *against*. And expanding from a notion of individual radicalism or extremism (and the practical issues it posed in terms of trusting access by a research team representing a major global corporation), we sought people with a range of political orientations and degrees of explicitness in agenda.

In the remainder of this paper, we describe the field study we conducted in the latter half of 2003, introducing some of the people we met and themes that emerged, and finish by revisiting the notion of infrastructure in light of what we learned, and sketching three broad areas for future ubicomp research and design. We see this work as experimental, not as a methodology that compares a treatment to a control group, but as an effort to seek novel perspectives on ubicomp and to give voice to potential users who have not so far been paid much attention to.

2 An Exploratory Study

As an initial ethnographic study of infrastructure, we set out to visit a range of people living in some way beyond the traditional bounds of one or more infrastructures. We conducted a total of 17 interviews. Most (14) were 2-3 hour home visits conducted by a two-person team (a social scientist as lead interviewer, along with an interaction designer as backup interviewer and recorder). Interviews were informal, asking people about their daily routines, neighborhoods, technology and media use, and interactions with people and groups outside the home. Discussion often was structured around a tour of the home, giving interviewers the chance to ask about technologies and other artifacts in the environment. This general discussion guide was amended to focus on particular areas or activities of interest (such as home schooling, living in a gated community, or, as one of our participants was said to be doing, going a year without buying anything) when these were known in advance, and flexible enough to accommodate veering off into such topics were they to come up serendipitously. These home interviews were supplemented by two workplace interviews, a group discussion over dinner, and miscellaneous other observations and collection of artifacts such as promotional materials and specialist magazines. Audio recording and still photography were used extensively, along with some video.

As this was an initial experiment, we limited ourselves to a convenience sample of mostly local participants, many recruited through as friends or friends. 13 of our field visits were in the Pacific Northwest, with the remainder (since gated communities are rare in Seattle and Portland) in the Phoenix, AZ megalopolis. To ensure exposure to a range of infrastructures and non-standard relationships towards them, we organized our sample around four categories: homeschoolers, gated community dwellers, security seekers, and disconnectors. The first two, which correspond to understood social categories, were recruited through friends of friends. Security seekers and disconnectors are artificial categories, with a few exceptions recruited by a marketing research firm screening its database of research volunteers based on a phone questionnaire that asked about events in the last 12 months. Security seekers had joined a group to make their neighborhood safer, created a "safe room," installed a home security system, or some combination of these. Disconnectors had stopped or almost stopped using the internet, TV, credit cards, or some combination. Though in some ways less interesting due to their artificiality, these market research recruiting methods introduced a useful level of randomness and surprise to our sample.

In defining a scope for our study, we faced a complex space of trade-offs, given the large number of parameters of interest within the general topic of infrastructures and their meanings in people's lives. Our choices resulted in sample that was predominantly from the US Pacific Northwest, white, middle-class, suburban, and technologically mainstream (neither early adopters nor laggards). Issues of privacy and security provided a set of unifying themes across all four groups of "off-gridders" we chose to recruit. Our discussions focused on the private and home, as opposed to the professional or work lives of our participants. There were important exceptions to each of these generalizations, cases that opened our eyes to whole sets of questions and contexts we hadn't considered. But insofar as what we found was determined by where and how we chose to look, it is important to acknowledge these trade-offs and resul-

tant biases upfront, and to call for future studies to address areas – such as different conceptions of infrastructures in other cultures – not examined here.

The following sections sketch what we found in our field visits for each of the categories of our sample.

2.1 Homeschoolers

Public education is one kind of ubiquitous infrastructure in the U.S., a complex system of buildings, buses, taxes, laws, standards, labor unions, certification authorities, advocacy groups, elected officials, etc., all of which functions (to a degree dependent on locality) to deliver educational services to children and, indirectly, their parents. More than ubiquitous, it's a mandatory infrastructure, insofar as it sets educational requirements for all children and requires payment through (generally) inescapable taxes. And for much of the population, it's unremarkable: though what goes on in school is certainly a common topic of conversation, but what school *is* is taken for granted. On the face of it, homeschooling challenges this.

The homeschooling movement (which had grown to include 850,000 U.S. children by 1999 [11]) is a complex and controversial topic, of which we obtained only a glimpse. Stevens [12] provides an excellent ethnographic and historical treatment, covering the struggle of both religious and secular homeschoolers to develop an underlying theory/vision, practical resources, and political and legal legitimacy. The homeschoolers we visited, though part of the evangelical Christian branch that dominates (perhaps 90% of) the movement, stressed the practical advantages of keeping their children out of the school system: increased customizability (allowing for differences in temperament, interests, and abilities of their children), control (knowing directly how their children were being taught, filtering out undesirable or dangerous social, intellectual, and physical influences), and convenience (fitting "school" into the family's routine and physical environment, adapting it to them rather than vice versa). They positioned themselves not as theorists or activists, but as good parents, simply taking advantage of an increased set of resources available to them to fulfill their obligations.

Consistent with what Stevens reports, our respondents did not object to the notion of school and authority-based *schooling* (lectures, exercises, memorization, testing, etc.) as the basis for education. They were happy to re-create, quite literally, schoolrooms in their homes and in their church community centers, and to adopt commercially available, pre-packaged workbook-, PC-, and/or DVD-based curricula. They were also willing to use the public schools for specific purposes. One family took advantage of public kindergarten as a means to build the social skills of their children in an open but safe context, before transitioning them to the more closed context of homeschool for subsequent years; another placed their children in one or two classes (foreign languages, which were difficult for the non-speaking mother to teach at home) at the local public school, through its outreach program to homeschoolers. At the end of homeschooling, students are faced with the challenge of gaining admission to college – of moving back onto the grid, so to speak; for this purpose, community college served as a useful transitional zone for establishing a formal transcript.

Given their perhaps surprising degree of agreement with at least the theory behind formal education, why do homeschoolers take on the additional burden of being

teacher/grader/school administrator, in addition to all their jobs as parent? First of all, our respondents, even the mothers, who clearly bore the brunt of the workload, all denied that it was in any way a burden. It was how they *wanted* to spend their energy, a way of expressing who they *were*. More surprising, to us, was what their characterization of public schools – for the most part not as ideologically incorrect (though this did come up, particularly around the teaching of evolution, which was seen as dogmatic and closed-minded) – but as *noisy*, chaotic places, full out out-of-control, rude children and a few harried, overburdened teachers/order-enforcers. "Just drop by your local school, you'll see that it's not at all like it was when you and I were that age," we were told repeatedly. Homeschooling was an effort to create a quiet, safe, respectful, orderly environment in which to care to their children's needs.

2.2 Gated Community Dwellers

As a ubiquitous, mandatory infrastructure, public safety has a number of interesting parallels to public education. The same diversity of component types – physical structures, vehicles, taxes, laws, standards, unions, advocacy groups, etc. – comprise both. Both exhibit the same mismatch between an ideals of equal service (and equal protection), and substantial, indeed correlated, geographic variation, be it in drop-out rates or crime rates. And perceived shortcomings have given rise to significant and controversial movements – homeschooling and gated communities – seeking privatization, quiet, and control. Nevertheless, there are important differences between how these infrastructures are perceived by their respective "discontents."

By 2001, 7 million American homes were in gated communities [13, p. 15], with large concentrations in the rapidly growing sunbelt retirement regions of the Southwest and Southeast, such as metropolitan Phoenix, where our field research took place. Gated ("fortress") communities and the closely connected phenomena of quasi-governmental homeowners associations are the subject of a substantial, very critical literature, decrying their implications for diversity, civil society, and public mindedness (see [13, 14, 15]). We found these criticisms echoed to some extent by the people we spoke with, particularly by some former gated community residents in their 20's who were hoping to leave Arizona in search of more diversity, excitement, and less of a "culture of fear." "I don't yet have children, but when I do, I want them to be able to play in the front yard without this making me look like a bad mother," reported one. They saw the gates more as symptoms of fear than as sources of security, and while the residents of gated community we visited were much more positive about their neighborhood, they all agreed that the gate itself was of little real security value, aside from keeping down the level of automobile traffic. Some suggested the gate actually encouraged crime, by keeping police patrols out, while presenting no real barrier to, for example, car thieves who could easily climb the fences, steal their objective, and drive it unchallenged through the checkpoint, which was locked from the outside only. Such views are consistent with general findings of little evidence for gated communities actually preventing crime, even if not inviting it [13]. And the people we visited all kept their doors locked, and either had or were planning to buy, home security systems.

If the gate is not about real nor perceived security, what is its significance? It's possible that it's a marker of community, but we found little evidence for that, either:

not only was there no gathering place for neighbors in the community apart from a collection of mailboxes at the side of the street, but in having residents sketch out and reflect upon their social networks, nearly all the people they felt close to lived beyond the gates. Instead, what emerged in our conversations was a notion of the "nice neighborhood" – predictable, safe, quiet, ready-to-move-in, and actively maintained through inconspicuous, gentle coercion. The gate, like the homeowner's association (which prohibited, for example, parching-prone citrus trees in front yards, a rule enforced by anonymous "narcs" informing on violators), was perhaps a necessary evil, at any rate an almost inescapable part of the lifestyle package Phoenix offered to its exploding population of middle-class immigrants and migrants from elsewhere. We discovered that, in Phoenix, to live "off the grid" as a member of this social class is to go to some lengths *not* to live in a gated community.

2.3 Security Seekers

Unlike homeschoolers or gated community dwellers, "security seekers" is not a natural category its members would recognize, but rather an artifact of our recruiting methodology. Instead of summarizing this group, we sketch a few of its members (names have been changed to protect confidentiality):

Pamela runs a small child-care service out of her split-level home in an inexpensive suburb. Her philosophy is to treat the children in her care as she treats her own, with an attitude of tough love and discipline. She extends this attention out into her neighborhood as well, keeping an eye out for suspicious persons and cars, and generally serving as a nosy neighbor – perhaps not well-liked, but respected, she feels. She once organized a successful neighborhood protest to expel a released sex-offender who had moved in with his parents next door; she would like to keep a camera trained on that property, but it's her understanding that laws prevent that. Compliance with state regulations for her home business is a major concern for her and quite visible in her den/care center, in which hand-drawn emergency exit maps have been posted, warning people not to try to evacuate through the garage, which due to her having walked in on burglars who fled out the garage door, she has now had locked from both sides. Above and beyond this call of duty, her den/care center is also a "safe room," in so far as she has made plywood barricades for the windows and has stockpiled enough supplies to last a week or two, should natural disaster or civil disorder require it. She is proud of her skills of frugality and self-sufficiency ("I know how to cook a *whole* chicken!"), developed over many years of hard economic times, following a crisis in which she and her husband both were laid off.

Tad is the head counselor for a city-run parolee halfway-house (a converted residential hotel) in downtown Portland. He oversees 40 men and women participating in a re-socialization program which aims to help recent drug-offender parolees find work and develop independent living skills for life after prison. Residents can stay at most 90 days according to their contract with the facility, and agree to random drug tests and regular meetings with counselors and parole officers. In addition to these formal requirements, residents are under lightweight, informal surveillance; in fact, Tad relies on their keeping tabs on each other, feeling that the resulting word of mouth keeps him better informed and in contact with his clients than any automated surveillance system could. Tad recently joined a neighborhood association to help make it a

safer place – particularly for his clients, who often must face the temptation of drug dealers who congregate just outside the facility's entrance. Tad sees cell phones as similar sources of danger for his clients, though he acknowledges their utility in helping them to find jobs and reintegrate into the community; instead of cell phones, his clients share a single payphone on the wall in the communal kitchen.

Loni's 5-year-old daughter calls their home a "bamboo forest." Though not exactly a forest, and though Loni and her family are not of Asian ancestry, the home does abound with Asian influences, including generous use of bamboo. Huge picture windows look out over a forested landscape in a low-density, semi-rural neighborhood. An atmosphere of calm (and ionicly-cleaned air, thanks to a Sharper Image appliance) permeates the house, at least during our mid-day visit when her husband and teenage boys were absent. (When home, the males are often relegated to a basement den outfitted not with bamboo but video games and home theatre system.) Despite appearances, Loni explains that her rustic neighborhood and peaceful house are not really safe; strange cars sometimes cruise by, and her home has been burgled multiple times, despite a nosy neighbor, her two large Bernese dogs, and an alarm system. She has had an alarm system for years, managed by a small firm whose principals she has come to know personally. Security precautions extend to her shredding any financial documents and maximizing her use of the Internet for financial transactions, which she believes to be more secure and resistant to identity theft.

Space does not permit sketches of the other home visits in this category here, but they were similarly diverse and evocative of the subtleties around the lived meaning and practice of "security." Some important general themes do emerge, however. Pamela, Tad, and Loni all identify themselves a protectors, caregivers, and caretakers for some domain, either a neighborhood, community, or household. They are thus personally invested in supporting a small-scale infrastructure, managing its connections (often threatening) to the outside, and ensuring that it provides a nurturing environment for people for whom they are responsible (professionally or familialy). Each is in some sense concerned with being "off the grid" (Pamela with her safe room, Tad with his halfway-integrated clients, Loni with her deceptively peaceful neighborhood), but in a stronger sense they are all involved in grid-creation, with creating a safe zone, a sanctuary and refuge of some sort in which care can be delivered. These they assemble from a variety of components, including mechanisms of surveillance, though even in Loni's delegation of this authority to an outside service, mechanisms that afford personal engagement.

2.4 Disconnectors

This last category is closest to our original idea of living "off the grid" – people who were disengaged from some pervasive media, information, energy, or financial infrastructure. As with the "security seekers," it's a mixed bag, so we present a couple noteworthy examples.

Margie and Brad live just beyond the reach of the electrical grid, in a remote valley in Oregon's Coast Range, 45 minutes from the nearest paved road, on a historic homestead site. "Out here, you're the power company, the water company, the transportation department, and sheriff and animal control," explained Ben (illustrating this last point by gesturing to a loaded revolver). Working as a freelance writer Margie

splits her time between there and Portland, whereas Brad lives there permanently, fighting a never-ending battle against gophers on his putting green and alder saplings springing up every time you turn your back. (One year they were called away for an extended period, returning to find their long driveway impassible due to saplings.) They have a gasoline generator to electrify the house wiring, usually only during Margie's stays, so she can recharge her notebook PC. When Brad is home alone he very rarely uses the generator and prefers to read by the light of a propane-powered floor lamp. Margie and Brad love being directly engaged, for better or for worse, with nature, and the lack of distraction it affords (and requires). In a few years they would like to retire there, though Brad is just recovering from a bad fall he suffered repairing their spring-fed water system and they wonder how long they can hold out.

Katrina lives with her husband and three children in an elegantly remodeled farm house in gentrified former Hippie community. She and her close network of friends live very comfortably, but she feels, wastefully. They have a lot of stuff – books, toys, electronics, clothes; more than they need, yet more kept coming into the house, bringing with it a negative "energy". Rarely did they re-use; it was so much easier to buy a new thing than to look to see if you already have it, she explains. Long interested in voluntary simplicity [16], she decided to conduct an experiment: "going a year without buying anything." What this would mean in practice was designed as a collaborative exercise with her family, including planned house meetings over the course of the year to modify and interpret the self-imposed rules if necessary. For her own part, Katrina was uninterested in drastically modifying her lifestyle and appearance of her home (her "no duct tape" rule headed off cheap-looking repairs), or in encouraging social transactions. So "anything" was defined to exclude comestible or consumable items (food, fuel, services), and "buy" was defined quite strictly, allowing for all matter of bartering, trading, and gift exchange. Between jobs at the start of the experiment, her husband was supported the experiment as means to economize. Children were brought in (or bought in) to the project with a promise of a trip to Hawaii at the year's end. At the time of our visit mid-way through the year, no major changes to the plan had been required (ruling light bulbs to be consumables was the extent of the controversies), and the experiment had become famous among her friends and their friends, facilitating donations and trades for needed items.

Though recruited as "disconnectors," strong desires for connection (with nature, in Margie and Ben's case, with local friends and community in Katrina's) emerged as important themes in these and the other visits placed in this category. Indeed, we found no one who was, or wanted to be, completely disconnected – ubiquitous infrastructures are, is turns out, hard to avoid. Across all our visits, the clearest examples of actual disconnection were involuntary – people who through accidents of economy or health found themselves thrown off the grid, and trying to clamber back on. In contrast, Margie and Ben, and Katrina, are good examples of a desire for selective and reversible disconnection. Rather than the extremist "off the grid" stereotype, they are in fact moderates, seeking to back away from too-easy access, temptation, and distraction the modern infrastructures of communication, transportation, and commerce bring with them, but not too much, and in the service of desires to connect to what is important.

3 Infrastructure, Reconsidered

Typically, when people think of infrastructure they think of the physical installations like public water systems, electrical grids, security systems, or transportation systems. These systems have very tangible points of contact. When a system isn't operating smoothly, like the power going out in the Northeastern U.S. during our study, or a pot-hole in a road, or a security gate that is broken, the results are physically felt. The there are other kinds of infrastructural systems that are less tangible but equally important. Many of our participants were actively engaged with (or against) institutional infrastructures such as school systems, churches, homeowner organizations, and retailers. Here the most visible points of contact (if you can get them to answer the phone) are agents doing "face work" [17] for the organization. (At a still broader level, Star and her colleagues [8, 18, 19] in their insightful analyses of categorizations and information infrastructures underlying communities of practice, take infrastructure as a relational and ecological term. Organizational points of contact, they point out, extend far beyond visible agents and into the very language, materials, and practices that constitute all manner of social arrangements.)

An intermediate level, or aspect, of infrastructure became apparent to us over the course of the study, a social or interpersonal level. People assumed many roles with respect to infrastructures they were developing – they took on roles and responsibilities such as teacher, caregiver, maintainer, nosy neighbor, donor, without necessarily becoming "agents" of a superordinate organization. Assuming these roles, they became a point of contact in a more direct, multivalent, and non-authorized way than an "agent." Contrast school teachers to homeschooling mothers, or Tad's commuting in to his job as parole counselor to Pamela's self-appointment as neighborhood mom. If we regard the institutional infrastructures as "professional," this third layer of infrastructure is at a less formalized and credentialed, more engaged and committed "amateur" level.

One feature of infrastructures is that they envelop people, hence their typical "invisibility." They also tend to envelop each other, becoming entire lifestyle packages [20]. On moves to Phoenix to "upgrade" one's life, buy a larger house, obtain some status, find a good school system for one's kids – and finds oneself living in a gated community, policed by a homeowner's association, unable to let one's kids play in the front yard. One might like to pick and choose which infrastructures to engage with or not, and to what degree, and there is some leeway to do exactly that, but it is heavily constrained. Breaking free of these existing constraints and established ways of living and creating a lifestyle usually takes effort at a larger scale than individual action and choice. For example, the homeschooling movement has done exactly this, creating models and justifications, providing resources, etc. The homeschoolers we visited were reaping the benefits of this past work, and presenting future parents with new questions to be answered about their identities, such as: are *we* homeschoolers?

One overall caveat from this analysis for the prospects for ubicomp is that infrastructure adoption is not likely to be a matter of an individual choosing an app, but of a community buying into a new way of living. Systems need to be designed that not only provide tangible benefits to "users," but which provide multiple symbolic and social values to people who will adopt many different roles and stances towards them. Along these lines, we now call attention to three areas for design.

4 Challenges and Opportunities for Ubicomp

4.1 Appropriable Infrastructures

In many cases, infrastructure is owned by outside authorities, and mediates a relationship between service providers and consumers. Consumers use the infrastructure, but they don't own it – they cannot appropriate it. They must abide by its rules, just as the services provided through the infrastructure conform to its constraints. *Using* the infrastructure can sometimes involve actually *inhabiting* it, as in the case of the gated communities we visited. Their residents had purchased an entire pre-packaged life-style, full of modern amenities, quiet, and "niceness." While they technically own their homes, they accepted (and more or less welcomed) restrictions on how they could modify them and behave around them. These restrictions were welcome in terms of using their home as an investment, ensuring its resale value, in unambiguous terms, without having to rely on messy and unpredictable processes of social negotiation with one's neighbors, for example.

Ubicomp is often understood in terms of habitable infrastructures, be they smart homes [21, 22], or urban districts overlaid by location-based services [23]. Service-provision and regulation-enforcement business models are familiar ones, which may yield great successes for ubicomp technologies, should the economics of provider costs and consumer benefits ever work out. Purveyors of such ubicomp environments would be wise to market them in terms of life-style and identity, leveraging the allure of being able to plug into completely designed system and magically transform one-self, or at least reinforce desired aspects of one's identity. For example, consider the services offered to evangelical homeschoolers, from curricula detailing how each school day is to be "lived," to ISPs that promise a bounded, regulated refuge within the wider, wilder internet in which to live one's online life.

However, there are downsides to merely using or adopting, as opposed to truly owning, through building or appropriating, infrastructure, and it is these we wish to call attention to as a challenge and opportunity for ubicomp systems to address. At a practical level, users are often faced by a mismatch between the standards or requirements of the infrastructure and the circumstances of their needs, desires, and abilities. Sometimes this gap can be addressed by purchasing an additional service or feature (as in supplementing the lack of perceived security by purchasing a home alarm system, or supplementing a homeschool curriculum by "purchasing" outside courses at a public school), but often it requires building (as in the specially constructed rooms we encountered in our home visits, ranging from home classrooms, to daycare safe-zones, to a library in a wilderness cabin; or in Katrina's construction – with buy-in from her family – of an evolving, publicized experiment in non-purchasing). At a more emotional level, users may experience a lack of engagement in or commitment to infrastructures that they have merely adopted, not to mention the emotional consequences of mismatches as noted above. Appropriation, in contrast, allows them to express their identities in a more active, self-constructed, gap-less way. In our study, this often surfaced in the form of care-giving and tending. Consider, for example, Brad's pride in taming the wilderness and being the electric company, etc.; Pamela's and Tad's active maintenance of a network of (caring) surveillance; or the homeschooling movement's insistence in creating a new way to educate children.

Gated community residents' reactions to the socially isolating aspects of their neighborhoods through active construction and maintenance of social networks outside their boundaries can also be seen in this light.

Ubicomp is implicated on both sides of this adoption/appropriation fence. In the form of standardized infrastructures deployed (and maintained) by service providers, they could well create gaps, unintended consequences, and emotional detachment due to mismatches between the package of services provided and local needs and desires. On the other hand, ubicomp is often considered in the form of ad hoc networks or do-it-yourself kits of self-assembling components that must function without benefit of a system administrator. Intermediate cases exist, as in the case of grassroots WiFi communities [24] in which networks of hot spots are far from self-assembling, but do only require "amateur" levels of skill to assemble into a form that can serve the community; assembly (and ongoing maintenance) can be seen as a kind of active caregiving and investment in the community. Indeed, there is no clear line between "adoption" and "appropriation," since infrastructures are often layered on top of infrastructures and construction consists of reuse and repurposing of existing commodities. More important, perhaps, than this distinction is ubicomp's potential not only to create gaps and mismatches, but to fill them as well.

4.2 Empowering Infrastructures

Infrastructures are about empowerment, in the sense of providing and controlling access to and facilitating flows of materials and services that in their absence would be far more costly to achieve. Physical infrastructures like electricity and water, and institutional infrastructures like school and legal systems, marshal and direct quite literally (though in infrastructure-specific senses) powerful forces. In exchange for empowerment, these infrastructures demand some element of trust. We entrust them to handle the messy and time-consuming details, to be reliable and accountable should they fail, and indeed often place our own health and security in their hands.

Ubicomp infrastructures have the potential to be similarly powerful, amplifying human capabilities through integrating many mechanisms of sensing, inferencing, and communicating. This harnessed, seamlessly integrated power will be attractive, if their designs can meet the requirements for user trust. More than attractive, it can even be life-saving, as suggested by work our colleagues at Intel are pursuing in proactive health, seeking to empower the elderly facing the loss of their homes due to cognitive decline [25]. Real or perceived, as a "luxury" or under coercion, needs for empowerment can motivate people to go to considerable lengths to seek out infrastructures that will address them. For example, our homeschoolers were willing to invest their children's time (at some possible spiritual risk) to use secular community colleges to meet needs for accreditation and legitimacy. As the phenomenon of gated communities suggests, even if the systems deliver fewer real benefits (e.g., in increased security) than they are perceived to, they may still succeed in the marketplace. Systems need not be perfect, nor perfectly perceived, nor perfectly trusted.

Reliance on infrastructure, however, creates its own problems and concerns. Our study of discontents illustrates how empowerment in some dimensions can lead to at least perceived disempowerment in others. In many of our interviewees, we encountered concerns about potential side-effects of relying on infrastructures to protect

them and cater to their needs. These ranged from homeschoolers wrestling with the line between protectiveness and over-protectiveness of their children, to people looking ahead to easing back in retirement but wanting to keep active and not lose their "edge," to survivors of personal traumas (becoming disabled, losing a home, etc. – being thrown off of the grid, so to speak) who were proud of the skills and self-sufficiency they had had to develop in order to cope. Infrastructure, for all its benefits – indeed, because of all its ready-at-hand benefits – was seen to bring also complacency, stasis, vulnerability.

Disempowering aspects of infrastructure can be addressed, recursively, by more infrastructure. Gaps created by one system can be bridged by others, etc. For example, one might imagine instrumenting homeschooled children to try to measure the "roughness" they are exposed to, and to adjust it over time to some optimum level. But aside from potentially infinite regress, this recursive approach seems to miss the point. The real question seems to be how ubicomp systems can be designed and used in ways that don't invite complacency and de-skilling. This is in fact a clinical question facing projects seeking to alleviate the burdens of aging, which risk creating cures that are worse than (or at least worsen) the syndrome. But it is a design (and ethical) question more broadly, whenever a system helps to alleviate a burden, and by so doing affects the skills that had developed for carrying that burden.

The challenge, then, as we see it, is for ubicomp systems that seek not to automate or even augment/amplify human skills but to exercise and celebrate them, to encourage active engagement, and provide resources to individuals and communities for continuous change and exercise. Such an approach can be seen in existing work on proactive health [25], on technologies to support political struggles of underprivileged communities [26], and promises to reframe the notion of security and safety from a passive commodity to an ongoing, embodied accomplishment [27].

4.3 Reflective Infrastructures

One theme that came up with surprising frequency in our interviews was noise, both literally and figuratively. Disorder and disrespect, conceptualized as loud, unruly behavior, played a central role in homeschoolers criticism of public schools. Our gated community interviewees appreciated the walls around their community for keeping out through traffic, with its noise and potential danger; they also appreciated (grudgingly) the formal rules of the community aimed at enforcing predictability and avoiding visual noise (the eyesore of the dead citrus tree in the front yard, for example). The security seekers were tuned into various sorts of suspicious noise in their neighborhoods, and sought to create in their homes (and in Tad's half-way house) safe zones of quiet and care. The disconnectors were concerned with waste and distraction, and (somewhat like Tad) with removing temptation.

Connecting to an infrastructure often brings with it the risk of noise. This noise may be in the form of nuisance, as when the infrastructure delivers the unwanted along with the wanted as its package of services, or when using the infrastructure requires extra effort or introduces extra complexity (as when the gate in the gated community has to be negotiated via remote control or access code). Or this noise may be in the form of distraction or temptation, as when the infrastructure invites overconsumption or overly-easy access to others.

Noise has also been acknowledged as a risk in ubicomp infrastructures as well. Noise in the form of unwelcome intruders and unpredictable behavior is the concern of research in security, reliability, and transparency of systems. In a humorous informance at the CHI 2002 conference, Bellotti and colleagues [28] enacted a scenario in which Captain Kirk's addressing "Computer: …" was met by a chorus of devices all answering "Yes?" – illustrating the risk of too much helpfulness (without enough deictic restraint) in a smart environment. And the potential downside of ever-increasing reach of computing and ease of access has been acknowledged from the beginnings of the field, in Weiser and Brown's [29] understanding that to be tenable ubicomp must be "calm" – that it must be attuned to the human perceptual system and its ability to switch attention between center and periphery.

Our study suggests that calm ubicomp – even calm, secure, reliable, univocal ubicomp -- may not be sufficient, at least not in a context of concerns over temptation and self-doubt in one's self-control. More than calm, many of our interviewees sought a kind of *quiet sanctuary* in terms of freedom from distraction, accessibility, and noise. Calm may not be enough if it is still too easy to re-center on appealing objects from the periphery. What would be enough, and whether people would actually adopt a system more strictly enforcing "allowed" vs. "unallowed" – instead of just wishing they were the kind of person who would/could live quietly – are hard research questions.

One path to "quiet" that arose from our interviews involves the idea of submission to a trusted other as coach, counselor, or mentor. Coincidentally, two of our respondents happened to be active in local Tae Kwon Do groups, and had ongoing relationships with a master teacher who oversaw their physical, mental, and spiritual development. Responsibility for development remained in the individual student, who was nevertheless expected to submit to traditional practices and to a hierarchy of authority. Themes of submission, though more to a system or community than a single person, also arose in our conversations with Tad in the half-way house, and with the homeschoolers pursuing a very demanding practice with the practical and spiritual support of a fellowship of believers. Perhaps ubicomp technologies could offer similar ways for people to put themselves in trusted relationships of nurturing surveillance and critique. Perhaps through technologies of self-monitoring and self-reflection, the trusted other could become, over time, the trusted self.

5 Summary and Future Work

Implicit in the idea of ubiquitous computing is the notion of infrastructure, which has received surprisingly little attention from the ubicomp community outside of purely technical investigations. Starting with an approach of looking for "trouble" (in Garfinkel's sense [30]) or "discontent" with respect to existing ubiquitous infrastructures, we ventured into the field to uncover practices around, problems with, and meanings of various infrastructures, as they were embedded in alternative and mainstream lifestyles. We consider the experiment was successful insofar as it uncovered a number of interesting themes and novel perspectives, and demonstrated the general viability of this approach for bringing out hidden structure.

As follow-on work, we have begun exploring a design space around intention submission to trusted others, and planning more targeted fieldwork to address in particular questions of temptation and transition surfaced in this work. We also intend to study how these issues play out in other geographies and other cultures, further from home, and in arriving at a more detailed understanding of the practices and materials involved in interfacing with infrastructures, beyond these more abstract concerns of identity and trust.

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