

# Enhancing Ubiquitous Computing with User Interpretation: Field Testing the Home Health Horoscope

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## ABSTRACT

Domestic ubiquitous computing systems often rely on inferences about activities in the home, but the open-ended, dynamic and heterogeneous nature of the home poses serious problems for such systems. In this paper, we propose that by shifting the responsibility for interpretation from the system to the user, we can build systems that interact with people at humanly meaningful levels, preserve privacy, and encourage engagement with suggested topics. We describe a system that embodies this hypothesis, using sensors and inferencing software to assess ‘domestic wellbeing’ and presenting the results to inhabitants through an output chosen for its ambiguity. In a three-month field study of the system, customised for a particular volunteer household, users engaged extensively with the system, discussing and challenging its outputs and responding to the particular topics it raised.

## Author Keywords

Interpretation, design, home, ubiquitous computing.

## ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION

Ubiquitous computing systems commonly rely on building a sensor-based model of the activities that people engage in and the contexts in which they occur. Familiar examples of this include applications such as electronic tourist guides [8] and the context-aware home research of Brumitt et al. [6]. Sensor-based modelling may allow computers to anticipate the needs of their users [19] offer new tools for care of vulnerable inhabitants [10], and even allow computers to represent and convey emotions [16].

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Problems arise when ubiquitous technology enters the context of the home, however. Integral to the nature of the home is that it provides a setting for a heterogeneous mix of activities and routines through which relationships and values are reproduced and renewed. Crabtree and Rodden [9] show just how profound the challenges are for design in domestic settings. Equally integral is that many of these activities, relationships and values are both idiosyncratic and highly personal. Meyer and Rakotonirainy [15] provide a recent review accentuating privacy issues and other deployment problems in the home.

Given these challenges, three basic questions arise:

- How is it possible, despite the current relative inability of computational systems to understand the full meaning and context of human activity in open-ended domains, to build systems that *sense and interact with people in a meaningful way* in the home?
- How can we build ubiquitous devices in the home that touch on issues that matter personally to users while *acknowledging users’ potential discomfort with intrusive sensing*?
- How can technology *support reflection, address emotions, and promote wellbeing* in the home?

## Ambiguity and Interpretation

In the research reported here, we sought to answer these questions by testing a system that embodies our primary research hypothesis: that compelling applications for the digital home can be based on sensor-based modelling, despite its limitations, *if we shift the responsibility for meaningful interpretation from the system to the user*. By using ambiguous outputs as a tactic to undermine system authority in favour of user’s interpretations, it becomes possible to create systems which benefit from the information that current sensor-based inferencing can provide while protecting user privacy, and, we argue, engaging users and stimulating reflection in ways that more clearly defined, functionally oriented systems may not.

Ambiguity is seldom embraced within traditional Human Computer Interaction; it can be difficult to see how an interface can be usable if the information it computes on and conveys is unclear. Nevertheless, previous work (e.g.,

[2], [14], [18]) suggests that ambiguity can be a positive strategy for design when the goal is for people not just to use a system but to engage with issues raised by it. By presenting users with situations that require them to play an active role in interpreting what a system is doing or what it is for, we can encourage them to develop understandings of their interaction which are relevant to their own lives, rather than conforming to a model embodied by the system.

Building purposefully ambiguous systems to promote user interpretation may provide an elegant solution to fundamental problems of using sensor-based modelling in domestic ubiquitous computing. People's interpretations can supplement those of limited systems. This would allow the use of deliberately constrained sensors to protect privacy. The result could be systems that encourage people's active engagement with domestic issues, allowing ubiquitous computing to support curiosity and reflection as well as task performance.

### The Home Health Horoscope

To test our hypothesis, we designed and developed a system that uses ambiguous output to convey system interpretations of domestic well being based on sensor data and simple pattern-recognition. 'Wellbeing', in this context, was a design concept chosen to resonate with concerns in the field such as using ubiquitous technologies to help care for the vulnerable [10] or to represent and reflect emotions [16]. We did not start with (nor do we advocate) a particular formulation of the concept, but used it to guide our initial user studies and later system design.

The basic logic of the system we developed is simple (Figure 1). Sensors track the state of important features of the home; inferences are made over patterns of these data to suggest changes to metrics representing the wellbeing of the home; and the resultant wellbeing pattern is output through a display for inhabitants to interpret. This design is meant to resemble the typical logic of ubiquitous computing systems proposed for home automation, emotional computing, aging in place, etc., in which it is assumed that sensor-based inferencing can build accurate representations of the home.

The trick is that the system we built reflects our scepticism that AI and allied techniques can actually build accurate representations, particularly of people's wellbeing. Thus the output is chosen to subvert the systems' authority, and to be somewhat ambiguous, inviting users to make their own

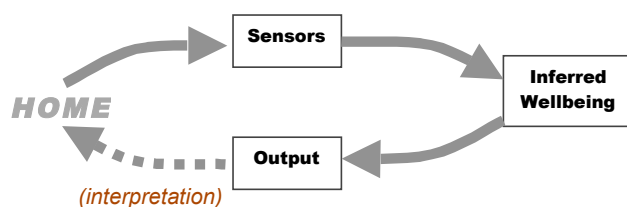


Figure 1: Basic system logic.

interpretations of, with and against those of the system. The suggestion is that, rather than those produced by the technology, it is *people's* interpretations that are the key output of the system.

Specifically, the system we developed used automatically-constructed 'horoscopes' to convey its inferences about wellbeing to users. We chose to borrow the language of horoscopes as combining requisite clarity with a useful degree of ambiguity and a questionable authority. Horoscopes are often assumed to make predictions, but they usually focus on diagnoses of current situations as well. In addition, horoscopes (of the sort found in popular culture) typically employ language that appears definite but remain ambiguous enough that people can project their own circumstances onto them. For instance, statements commonly take the form "while you are usually X, sometimes you are not-X" (where X might be cheerful, gregarious, organised...). This raises the dimension X while allowing readers great flexibility in determining their position upon it. Finally, horoscopes are a culturally familiar genre of enduring popularity, found in a variety of print and electronic media (e.g. mobile phones). They present a prime example of a situation in which people 'play around' with ideas. Many of us are not committed to the metaphysics of horoscopes, but still read them to see if they 'fit'. This attitude of 'entertaining an idea' is one we wanted to explore with our system.

In the rest of this paper, we describe the design and deployment of the Home Health Horoscope. In the next section, we discuss the results of preliminary interviews about how wellbeing might manifest itself in the home, and then more detailed ones with a volunteer household we focused on in developing the system. In the following sections, we describe the system implementation, and then an extensive field trial of the prototype with the volunteer household. We conclude with a more general discussion of the system, how it might be developed, and the prospects for this approach more generally.

### FINDING MANIFESTATIONS OF WELLBEING

The Home Health Horoscope is based on the assumption that sensor-based inferencing can only achieve an approximate representation of wellbeing at best. Nonetheless, using automatic inferencing to construct even an approximate representation is a challenging task. In particular, it requires addressing two fundamental issues:

- how to deploy sensors to pick up information relevant for domestic wellbeing
- how to map patterns of sensor readings to particular representations of wellbeing

Given the idiosyncratic and situated nature of domestic life, finding general answers to these questions seems difficult at best. Therefore, our approach was to explore them with a

particular volunteer household and to customise the system for that household. In order to find an initial orientation for the exercise, we conducted informal interviews with a small number of other volunteers.

### Home Visits

In order to inform our intuitions of how wellbeing might be manifest in the arrangements of the home, we undertook a number of informal, on-site interviews with volunteers in London (2) and Cornell (8). The volunteers were drawn from an existing panel and from friends-of-friends respectively. Typical visits included two or three researchers and one or two household members, and involved a tour of the home, accompanied by an ongoing discussion about how 'wellbeing' might be understood in their circumstances. We took pictures – often more than a hundred per visit – to capture scenes relevant from our conversations, and annotated them for later viewing. In the case of one of our London volunteer households, we were able to complement informal interviews with knowledge gained from a prior ethnographic study the household had been the subject of.

With experience we developed a loose repertoire of questions that seemed effective at eliciting information about how wellbeing might be sensed. A basic strategy was to ask people not how sensors might register wellbeing, but how they themselves might perceive the wellbeing of their housemates. For instance, we might ask how they could figure out what mood their housemates were in if nobody was at home, or what happened when they argued, or how we might tell if they were busy or relaxed.

One of the most noticeable findings of these interviews was that the organization and activities of the various households were idiosyncratic and varied, and thus that specific evidence for wellbeing was not at all consistent between homes. For instance, dirty dishes in the sink might be a normal state of affairs in one household, and a sign that domestic routines have broken down in another. Moreover, households varied in the factors that were most relevant for wellbeing. For example, controlling clutter might be a key concern for one household, while an active social life might be paramount for another. It soon became clear that the design of sensors and wellbeing inferences would need to be tailored for particular households.

Nonetheless, our informal study also suggested some consistency in elements of the home that might be implicated in assessing wellbeing. While details might vary, regularities might be captured using [1] or [9]. Examples include:

- How space is used in the home can reflect emotionally-laden social patterns. People described places where they would routinely socialize, or work, or to which they would withdraw to be alone. How multiple people

used the spaces of the home was also significant; for instance, one volunteer described how he and his girlfriend separated and rejoined one another when fighting in terms that suggested a kind of ritual dance of disagreement.

- The timing of particular events can reflect activity patterns with implications for wellbeing. People told us about their routines around the home, and it was clear that variations in timing – an early breakfast, queuing for the bathroom, hanging out late at night – could be a symptom and a cause of notable emotional states.
- The placement of particular fittings may also be indicative. For instance, a musician described how a box used to keep guitar plectrums commonly migrated from its 'proper' place as he worked. It was always returned at the end of a session, he reported, unless he was overwhelmingly busy or stressed. Similarly, other volunteers reported that a toiletry bag moved only when the owner was travelling, or that a jewellery box was only taken out of storage to prepare for a night out.
- Using certain pieces of furniture can have significant meaning. Kitchen tables were often the site of social encounters, while certain living room chairs might be used for relaxing in front of the TV. In some cases, items might only be used for very particular activities with relatively clear emotional implications.

Despite the variability of specific household routines we found, then, the interviews suggested that regularities may be found in the domestic elements implicated in diagnoses of wellbeing, and in the kinds of sensors that might be used to track those elements. More concretely, for our study, these findings were useful in more detailed conversations with the volunteer household for whom we developed the prototype system we report here.

### F and Z's Household

We pursued further development of the Home Health Horoscope with a volunteer household in London, selected after telephone conversations with respondents to an advertisement we placed in a local want-ad newspaper.

Located in a large 5-bedroom semi-detached house in a northern suburb of London, the household included F, her husband Z, and a shifting assortment of their three children (all in their 20's) and their various partners, friends and lodgers. F, our main contact, was clearly the 'head' of the household in the sense that she managed day-to-day organization and maintenance of the home ranging from shopping and cleaning to assigning bedrooms to occupants as people came and went. Based at home, she was not only busy with these tasks but also with various business endeavours, including investments in new property and speculative ventures ranging from internet commerce to new forms of fashion footwear. F's husband Z was a software engineer who travelled a great deal and was rarely

home during our visits. Other occupants changed regularly, and in fact the dynamic occupancy of the home was one of its most striking features. Residents varied between three and ten with about six being the norm, and we rarely found the same people living there over the numerous visits we made in the eighteen months it took to develop the system.

We visited the household about half a dozen times, while developing the prototype system, in an iterative attempt to understand how wellbeing might be manifest in the household, what sensors might be appropriate and where they might be placed, and the how sensor data might be mapped to wellbeing. Visits were usually conducted with F in the mid-afternoon by two or three members of the team and, as with the previous home visits, consisted of informal conversations as we wandered around the home.

### **From Stories to Sensors**

Over the course of our visits, we converged on a set of nine sensor placements based on F's stories and our perceptions of the technical possibilities. Here we describe a sample of the sites we chose both to give a feel for the organization of F's house and the logic behind our sensor deployment.

#### *The Cleaning Cupboard*

The daily operation of the household was a primary concern for F, and she took great pride in the organization and efficiency with which she pursued cleaning, shopping, cooking and laundry (she routinely took care of all these activities even for adult lodgers). For instance, we often found that she had already prepared dinner in the morning to be cooked in the evening. Cleaning was a particularly important routine, she told us, that she routinely pursued on a daily basis. When questioned, she claimed that the only reasons she would not clean on a given day were because the household was in chaos or because she was depressed. Either way, it appeared that skipping the daily clean was a clear indication of negative wellbeing.

As with many of her household routines, F prized efficiency in her cleaning and used a number of labour-saving products (e.g. disposable floor wipes) stored in a cupboard in her kitchen. She told us this cupboard would routinely be opened to get these supplies when she cleaned, but rarely on other occasions. Thus we decided to place a sensor in the cupboard as a proxy measure for cleaning events.

#### *The Kitchen Door*

F's household was extremely sociable. Often the members would gather to eat meals together, or spend time in the living room, or hold barbecues for neighbours and friends. This was reflected by the fact that the door between the kitchen and living room was usually left open, allowing a flow of people to move freely through the house. Nonetheless, F reported, on occasions subgroups would form in separate rooms. Often this happened when F and Z wanted to spend a quiet evening watching TV while the

'kids' socialized elsewhere (often in the kitchen). On these occasions, the kitchen door would be closed. It might also be shut when F left people in the living room to conduct private business over the telephone, or when a subgroup ate a meal while others socialized in the living room.

The kitchen door, then, appeared roughly indicative of the current social cohesion of the household. All things being equal, we reasoned, if the door was shut the tone of the house was generally private, while when the door was open the household was relatively social. Thus we decided to site another sensor on the door to report on its current state.

#### *The Love Seat*

The dynamic social nature of F and Z's house often meant it was difficult for them to spend private time together, and sometimes this was a problem. One ritual F told us about involved Z bringing her coffee in the morning before he went to work. While she drank it, she said, he would often sit on the loveseat built into the bay window of their bedroom and they would enjoy a morning chat. Thus morning activity on the loveseat appeared to be a good indication of a happy relationship between the two.

The loveseat was also involved in less positive attempts to seek privacy, however. F told us that when the household was particularly busy (e.g. when they had four exchange students staying in one of the bedrooms) it could be frustrating for her and Z to find time together. On these occasions, they might resort to their bedroom in the evening to find a quiet space. In this account, evening loveseat activity appeared to indicate that the household was too busy, putting strain on F and Z's relationship.

#### *Stories and Sensors*

As these examples indicate, our conversations with F supported an iterative process in which we familiarized ourselves with:

- the routines of the household
- how variations might affect the local sense of wellbeing
- particular objects and sites involved in those routines.

Clearly our understanding of these matters was provisional and incomplete. Nonetheless, by the end of this process we had identified nine sites for sensors that seemed likely to provide indicative information about domestic wellbeing, as well as a rich understanding of how these sites were implicated in ways that might inform system inferences.

#### *Metrics and Rules*

In discussing the volunteer household, we found ourselves articulating aspects of the household's state that might be relevant for wellbeing in terms of dimensions such as 'busy', 'cheerful', 'private' or 'disordered'. It became clear that thinking about dimensions such as these also

provided a way to express the themes or issues commonly raised by popular horoscopes. Thus we decided to use these ‘wellbeing metrics’ as a core representation for the system. Similarly, we chose to use rules to represent the ways that sensed states and activities might be translated to patterns along these metrics for pragmatic rather than theoretical reasons. Rules allowed us to articulate our observations clearly and easily, and in a modular fashion that did not require explicit integration. These wellbeing metrics and rules formed the core representation of ‘wellbeing’ in our system, allowing us to map from sensor data to horoscope outputs as we describe in the following section.

## IMPLEMENTATION

Figure 2 shows the technical architecture of the Home Health Horoscope in stages corresponding roughly to those in Figure 1. In this section, we outline the implementation of each stage of the system.

*Sensing and data storage.* The system used Intel Motes, small devices that combine microprocessors with wireless communication and the potential to incorporate a variety of sensor devices (see <http://www.xbow.com/>). We used Crossbow System’s MicaZ motes, piggybacked with MTS310 sensor boards. The motes were programmed as a mesh network running the XMTS application, and were interfaced to a PC via Crossbow’s Mote-View software. Data was logged to a PostgreSQL database, at a (nominal) rate of around one entry per 4 seconds. This allowed us to use more mainstream technology design tools (e.g. SQL, PHP, and Flash) to work with the data.

*Data Preprocessing.* We used PHP scripts and SQL queries to preprocess the stored data in a variety of ways, and also to output data summaries and subsets for display via a Macromedia Flash application. Most of the preprocessing created statistical summaries of the sensor data, for instance calculating the total time individual sensors were above threshold in a given 24 hour period (with the thresholds set to correspond to changes of state in the household such as doors opening, water running, etc.), or the number of times a threshold was crossed (i.e., the number of times a door was opened or closed), etc. These summaries translated the raw sensor data into a variety of numbers and durations. Rolling weekly averages of the summaries were stored as well, allowing us to determine, e.g., whether today a door has been open more than usual.

*Rule-based Inferences.* Summaries and averages of sensor activity provided the basis for our simple inferencing engine. This performed a daily mapping from the last 24 hour’s sensor data to the wellbeing metrics. This was achieved by a series of about 50 rules that interpreted sensor patterns in terms of the metrics (often with some activity like a communal meal or private conversation implied). For example, a rule might express that if today the kitchen door has been closed more than usual for the

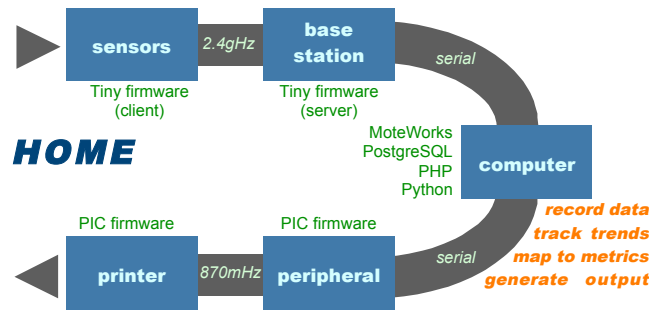


Figure 2: System architecture.

week, the household is particularly private and the corresponding metric should be incremented. This simple rule structure allowed us to express regularities in the home reasonably well, although it could be extended to express more complicated household patterns.

*Display generation and output.* Once the metric levels for the day were calculated, we used them as parameters for a Python script that generated the actual text that was displayed to users. We constructed ‘horoscopes’ by combining sentences culled from around 10,000 online horoscopes and categorized using a combination of automatic classification and hand-selection. The sentences were classified according to the wellbeing metrics, allowing the metrics to serve as the bridge between sensor data and output. To generate its output, each day the system identified the two metrics that had changed the most, chose random sentences (which were not reused) from the corresponding categories, and concatenated them to form the daily ‘household horoscope’. This was printed by a small tickertape printer, similar to those used for cash register receipts, controlled by a PIC chip wirelessly connected to the base computer (Figure 3).

## FIELD TESTING THE HOME HEALTH HOROSCOPE

We deployed the prototype Home Health Horoscope in F and Z’s home about eighteen months after first contacting them, and left it in the household for about three months. In this section, we give an overview of the field trial and highlight particular issues that arose. In the next, we discuss the household’s reaction to the system in more detail.

### Making the System Work

Installing the system involved mounting the nine sensor boxes in various locations around the house (Figure 4), siting a laptop with a connected Mote receiver onto a high shelf in the kitchen, and placing a wirelessly connected printer unit onto an often used kitchen counter. We had designed the sensor devices with various straps, hooks, etc. to ease installation, but still had to negotiate practical contingencies such as making room in the cleaning cupboard to fit the sensor, choosing a table leg that would not be knocked against and so on.

Overwhelming these physical considerations was the need to ensure radio connectivity between the sensor devices and the base station. In fact, during our first installation attempt we were unable to achieve complete coverage, and had to return several weeks later with about ten wall-powered repeater units to ensure adequate connectivity.

That it takes work to make a system work (cf. [5]) is not a novel observation. It is worth highlighting here, however, because the time it took to site the system, physically and electronically, affected its introduction to the household.

### Introducing the System

During our initial visits, we had made no attempt to disguise our interest in wellbeing and the ways it might manifest in the home. However, we deliberately avoided telling household members about the Home Health Horoscope system we intended to develop. This was somewhat awkward as F, in particular, often speculated about the sort of system we might be intending. We thought it important, nonetheless, that the household not anticipate details of the system before it was even complete.

Installing the system was not a trivial process, taking several hours over two separate visits. Naturally, F and various other members of the household became curious as we moved from room to room in the house, poking into corners and asking advice about convenient locations for the sensors. In keeping with our preliminary visits, we made the technologies we were dealing with clear both through direct answers to questions and the discussions we had amongst ourselves, but refrained from telling them about what the system would do in the end.

Even when the system was fully installed, we gave only the briefest of descriptions of what they should expect it to do. We told them that the distributed sensor devices were indeed meant to monitor aspects of the home, but concentrated on assuring them that this did not include either video or audio recording. We also told them that the sensors fed into a system that would produce periodic

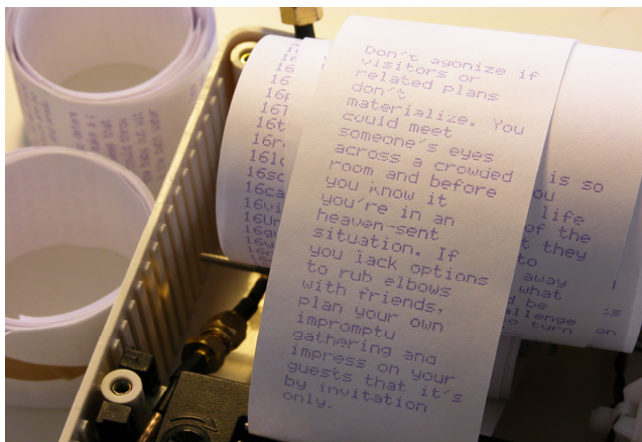


Figure 3: The horoscope printer.

feedback, but did not tell them when it would occur or that it would take the form of a horoscope.

We avoided telling the household very much about the system throughout the process of development and installation because we did not want their experience with the horoscopes to be overly coloured by their anticipations. Nor did we want to prejudice their perception of the system at work, either by telling them that its output was meant to evoke the genre of horoscopes or by making an explicit connection between the output and the sensors. Instead, once we had installed the system we merely told them that it would produce outputs once a day and little else.

### Assessing a Lightweight System

In planning how to assess the household's engagement with the prototype system, we were mindful of the sort of experience we expected it to afford. The Home Health Horoscope produced its output once a day at 8:30 AM. The distributed sensor devices might remind householders about their presence at other times (and in fact were originally designed to be bright orange, until F objected that this would clash with her carpets), but overall we expected interaction with the system to be relatively occasional and spontaneous, requiring little effort on the part of users.

We did not want to overwhelm the lightweight experience we expected to produce with the process of evaluation itself. Thus we decided to avoid methods that would require the householders to make substantial and continuous effort, such as written or video diaries. Instead, we chose to focus on the household's ongoing impression of how the system's output – the horoscopes – made contact with their lived reality. To this end, we planned three basic forms of assessment. First, we asked the members of the household to jot notes on the back of the horoscopes themselves to note their impressions in an impromptu fashion. Second, we commissioned an independent documentary filmmaker to produce a video documentary of the household's experience, without telling him anything about the system or our intentions, and with explicit directions that he should be as critical or positive as he felt the situation warranted (see [13]). Finally, an ethnographer in our group periodically visited the household, particularly towards the end of the trial, to capture the household's conclusions about the system.

A third source of information was unplanned, but turned out to be particularly useful. Because we wanted the sensor housings to be independent from electricity outlets, we used batteries to power them. But because they were relatively power-hungry, this entailed visiting the household on a weekly basis to replace the six rechargeable AA batteries per sensor with fresh ones. These visits took more than an hour on average, and provided a valuable opportunity to engage members of the household in conversations about the system. This was all the more valuable because the team



Figure 4: Sensor installations. From left to right: kitchen table, kitchen door, and understairs cupboard.

member was perceived, and perceived himself, in a maintenance rather than research role. Conversations often revolved around whether the system was operating ‘normally’, creating a situation in which reflecting on what ‘normal’ meant was natural for the family.

In the following section we discuss the household’s experience with the system.

#### LIVING WITH THE HOME HEALTH HOROSCOPE

F and Z’s household lived with the prototype Home Health Horoscope for about three months. Despite its simplicity, during this time the system seems to have occasioned a rich set of views to be formed, issues to be raised, and experiences to be had. In the following, we organize our observations of these into a set of overarching themes.

#### Trajectory of Appreciation

As John Bowers has noted, the experience of living with systems can often be characterized by a *trajectory of appreciation* that changes over time (see [12]). Individual trajectories will vary, of course, but in our experience many are characterized by an initial excitement of expectations, tempering as these meet with the realities of the system, acceptance and potential appreciation of the system as it is, and a resolution in which the system either becomes a mundane part of everyday life or is abandoned. It is important that field trials be designed to allow for at least the first three of these stages, lest the period of initial excitement be mistaken for a long-term relationship. In fact, it appears that it is in the transition from disappointment to acceptance that the most useful research insights can be gleaned, as it is in this period that volunteers are most reflective about their experience.

Our reluctance to describe the system to the family before or during the trial influenced their trajectory of experience in notable ways. Rather than being characterized by excited, thwarted and readjusted expectations, much of their process of learning about the system was overlaid with their attempts to understand exactly what it was about. Over time, their interpretations settled, though not towards a single account, and they never ceased speculating entirely. Towards the end of the trial, their engagement with the

system appeared to slacken, but it never stopped entirely and F persisted in reading and thinking about the system’s output every day.

#### Questioning Intentions

Much of the household’s engagement with the system revolved not around the implications of the horoscopes, but about the wider intentions of the system as a research project or potential commercial product. This took several forms, as we discuss below. Linking them all was the household’s awareness of the system as including not just sensors, computer and output, but a team of researchers who had made numerous visits, crafted the system for the household, and periodically visited while the system was running. That is, in addition to forming a relationship to the ‘voice’ of the system itself, as we had intended (and will discuss later), they also saw the experience as including the design team as an integral component.

#### Who the Horoscope Spoke To

We intended the output of the Home Health Horoscope to be read as applying to the household as a whole rather than individual member(s) within it. The nature of the sensors, which tracked salient spots in the house rather than, say, the movements of individual members, might also be expected to convey this intention. Members of the household, however, decided relatively quickly that the horoscopes were directed exclusively to F. This might be because traditional horoscopes tend to be consumed individually, or because the ‘voice’ of most horoscopes is not directed at a group. It might also be because the household recognized that F was most often in the home (and in fact her activities might have been reflected most often by the sensors). Some evidence for this latter interpretation came when, on a battery-changing visit shortly after F had returned from a week-long holiday, members of the household told us that in her absence they had read the horoscopes as directed at her son P.

It became clear that most members of the household engaged with the system less than F and Z. This may be because they did not interpret the results as applicable to them, but in any event younger members of the household reported that they only looked at the outputs on occasion.

*The Home Health Horoscope as Talking Point*

For F the system was “intriguing, a talking point”. “People who know us like it that we are doing an experiment”. We have seen features of this in other field trials we have conducted (e.g. [12]: friends, neighbours and relations become intrigued by the designs and people enjoy talking and speculating about what is going on. The generational difference noted above also appeared to have carried over to visitors, however, with the children’s visitors only mildly engaged by the system, while friends of F and Z’s were reportedly more intrigued.

It is important to distinguish the forms of engagement the presence of a novel system in the home give rise to. Some of these simply concerned the appearance of a novel, and even unique, gadget in the home. Others revolved around the system as a research artefact, focusing on the (potentially suspicious) intentions of the research group. Still others, however, addressed the intentions of the horoscopes more directly, providing new views on how these related to the household, its state and activities, and the wellbeing of its members.

*Conjecture and Suspicion*

Many of the people who encountered the Home Health Horoscope, both household members and their acquaintances, became suspicious from time to time about what the sensors were doing. This reached fever pitch early in the trial when one of F and Z’s children was involved in an unspecified intrigue and we were briefly suspected of spying on them. This subsided relatively quickly, but throughout the trial a certain uneasiness about technologies clearly related to surveillance was apparent, and our relationship with the household seemed crucial in their willingness to act on the belief that the system was not invading their privacy in any gross way.

Speculation about hidden motivations persisted however. Most centred on our ‘true’ intentions with the research. Z, in particular, was frustrated that he could not understand the relationship between what the horoscope was saying and what the activity was or had been around the house. He considered doing experiments to investigate how they might work – maybe testing a particular box to see if it was sensitive to the sound of raised voices – but this didn’t seem like a particularly urgent thing to do for a man tired after he gets home from work. Instead, he began to question whether something else was going on. In the documentary, he conjectures variously that the horoscope is merely there to provide an excuse for the sensors, that they are tracking room usage, movement around the house, or perhaps are themselves empty, serving simply as an excuse to allow access to their home. This is all in the context of a conversation with F that is being recorded for the documentary and does not seem very serious, but it is clear that the volunteers speculated, at least occasionally, that there might be some hidden motivation behind the

installation – added evidence for this is the attempt by one of the younger inhabitants to take apart a sensor box for inspection.

F’s interpretation of the system was least suspicious and closest to our actual intentions. Perhaps this is unsurprising as she had most contact with us and with the installation and maintenance of the sensors themselves. Throughout the trial, however, her interpretation was only one of several. Even after the equipment was taken away, the household gathered eagerly when we visited a last time to debrief them and ‘reveal the truth’ about the system.

**An Uneasy Relationship...**

While a significant amount of time seems to have been spent wondering about potential veiled motives for the research, the household – or at least, F and Z – also reflected on what they liked and disliked about the system as a potential product.

Both F and Z were uneasy with the output appearing as a form of horoscope. While we intended to borrow horoscopes’ ambiguous language and their ability to invite speculation, F and Z were also sensitive to the causal models behind ‘real’ horoscopes and to their cultural connotations. They also objected to the particular tone of the horoscopes. As Z put it: “their language is not in tune with the home”. F felt they were too dogmatic, and thought they might be more effective if more tentative, referencing particular horoscope compilers in making her point. As she became more convinced of her interpretation of the system’s intentions, she suggested (several times) that we use psychometric testing to better understand the appropriate language for particular audiences: “Don’t talk to a tough builder about the inner child.”

Beyond questioning the use of horoscopes in general, or their style in particular, F and Z queried whether and how the horoscopes reflected their perception of the household. As we have seen, Z was unsure about how the horoscopes reflected the basic activities in the household as measured by the sensors. F thought that the idea of “an electronic personal advisor would be quite clever, if it were based on accurate behaviour, if the software was accurate”. However, she was sceptical whether such a thing would be possible without embedding a “proper understanding of things”. For F, this would seem to involve a complete “psychology of people” being embedded into the design both so that people’s movements and activities could be better understood and so that the language of the advice could be better formulated. While F believes that people do give off subtle energies that can be interpreted by others, she thought that the challenges for sensors to do this in a meaningful way were immense: “the sensor would have to measure what for people are instinctual understandings”.



### ...A Relationship Nonetheless

In many of her comments, F seemed to accept that the system was able to detect gross patterns of household state. What she was more doubtful about was the judgements it made on this basis. For example: “When everyone moved out two years ago, it was very quiet round here. But if the horoscope had said ‘you’re calm’ it would have been way off. It was really turmoil for me rattling around here with no one else around.” There is a clear distinction made here between the ability of the system to track activity and its ability to infer wellbeing from these data.

F did act on the horoscope’s advice on one notable occasion, however. She was in the midst of buying a house, and, impatient with progress, was on the verge of ringing the solicitor. On reading the horoscope that day (“... *Thinking before you speak and act will keep you out of trouble. The real source of your trouble is a lack of self-control.*”), she reported: “I decided to say little and find out what they had to say before I opened my big trap!” The upshot was that the sale went through – a fact that F, at least, attributed to the following the horoscope’s advice.

Most of the time, though, F did not accept the system’s advice so readily. For example, she told us on several occasions that the system characterised her as too busy, and objected that although she *was* busy, she *enjoyed* being busy and would be unhappy otherwise. What she objected to was not that the system was wrong about her level of activity, but that it was moralistic and mistaken in its advice on that basis. In situations such as these, F countered the system’s interpretation of her wellbeing with her own. The system output seemed successful at raising issues of relevance to F and, on occasion, Z: how busy they were, work / life balance, etc. They did not take its output as authoritative, however, but instead as an opportunity to articulate their own judgement of affairs. This relationship – puzzling, even irritating – may lead to the perception that the Home Health Horoscope did not work successfully in their home.

Remember, however, that the system was designed to encourage peoples’ interpretation to supplement those of the technology itself. We borrowed the combination of assertiveness and ambiguity common to horoscopes precisely in order to problematise the system’s authority and encourage people to ‘correct’ it with their own judgements. From this point of view, we argue that the system was indeed working well when F and Z accepted its apparent judgements of overall domestic activity, as well as the dimensions of wellbeing that might plausibly be of particular concern, even when they rejected its interpretations about such matters for their own.

In making judgements about wellbeing that the household members might disagree with, the Home Health Horoscope can be seen as taking a role as another voice in the household, rather than an authority [cf. 17]. In some ways,

it is similar to that of E, an old friend of the family who happened to visit while the system was installed. He became intensely engaged with the system, and tended to agree with the judgements it made: “I read those things, and I think they’re spot on”. When F claimed that the system was wrong to admonish her for being too busy, for instance, E objected: “You run around like a blue arsed fly, and that thing tells you to, it tells you to slow up!” The point is not that the system, or E, or even F was ‘right’ about wellbeing. Instead, it is that each could potentially play a role in commenting on, and even instigating, a more-or-less informed conversation about it.

From this point of view, then, F and Z’s relationship with the Home Health Horoscope, although troubled, frustrating, and sometimes filled with doubt and suspicion, nonetheless *was* a relationship. As such, the system did serve to highlight issues of wellbeing in the home for discussion, based on a set of sensors that were not perceived as intrusive, and without usurping F and Z’s authority over them. There are clearly opportunities and requirements to refine the system in new iterations, as we discuss in the next section, but there are also clear signs of success for this approach to spurring user interpretation.

### DISCUSSION: OPPORTUNITIES AND PROSPECTS

There are a number of possibilities for making iterative refinements of the Home Health Horoscope. The system’s ability to make responsive inferences would be improved if more sensors and more complex and nuanced rules were used. It might also be possible to use algorithms that allow internal representations to emerge (e.g. neural nets) rather than depending on articulated ones such as our metrics and rules; such an approach might also lead to unexpected insights about wellbeing in the home.

Our experience has also led us to consider alternatives to found horoscopes as an output medium. They are appealing for combining cultural familiarity and ambiguity, and may be more engaging than anodyne forms of generated text. Horoscopes present several disadvantages, however. People may not find their wider cultural connotations appealing. Short sentences are difficult to classify automatically. They often imply an unintended or inappropriate context. Thus we are exploring other forms of text, such as poems, song lyrics, or news articles – potentially chosen in accord with user preferences – as an alternative form of output.

Perhaps most important, in deploying systems meant for open-ended interpretation and orientation, details of the deployment itself become crucial. F and Z’s speculation about the motives and intent of the system were clearly spurred by our reluctance to say too much about it. The ‘object of design’ seems to shift if one takes these observations seriously. We are not just designing systems but systems in a context of deployment, interpretation, appropriation and appreciation. How we introduce systems,

what we say about them, becomes an important part of this extended ‘object of design’ – even more critically when the system itself is not an orthodoxly utilitarian one.

### Harnessing the Power of Automatic Inferencing

While there is clearly room for improvements, we believe the Home Health Horoscope provides an existence proof of the potential benefits of combining automatic inferencing and ambiguous output to encourage user interpretation.

Our approach is one of several strategies seeking to address the problem that sensor-based data is often not, in itself, directly informative of activities and contexts, and that automatic interpretation often cannot adequately reflect the situated and contingent nature of human activity [11]. Some do away with automatic interpretation: for instance, [4] describes a system that supports ‘social awareness’ by presenting sensor data back to users. The intention is that appropriately designed data presentations will enable users to make sense of the activities of colleagues without the data being directly interpreted by the system. Others even do away with sensor data: for instance Benford et al. [3] report a game in which mobile players self-report their position, rather than relying on, e.g., GPS data. Close analysis revealed that users’ self-reports were influenced by their sense of their ongoing activity and how displaying that might be of use to others. This work provides another example of allowing users to imbue data with a sense of the activity the data reflect rather than attempt to automate data interpretation (or here, even, many features of data capture). Perhaps closest to our approach is work by Sengers et al. [18] or Romeo et al. [17], who use sensor data and automatic interpretation, but convey the results through nonverbal outputs to indicate that machine inferences may be ‘alien’ and require interpretation.

The approach we take here does not abandon automatic interpretation or sensor data, nor does it blur its output or make it appear ‘alien’. Instead, it uses output that balances clarity with a problematic authority to encourage user interpretation, suggesting that the system output should be held accountable to users’ own perceptions and interpretations. In this it reflects discussions suggesting system accountability [7], but instead of systems providing their *own* accounts, it suggests that systems can be designed that encourage people to hold them *to* account. In this way, we combine the advantages of sensor-based modelling with those of user interpretation by creating a dialog between the two.

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### REFERENCES

1. Alexander, C, Ishikawa, S, Silverstein, M, Jacobson, M, Fiksdahl-King, I, and Angel, S (1977). *A Pattern Language*. Oxford University Press.
2. Aoki, P and Woodruff, A (2005). Making space for stories: ambiguity in the design of personal communication systems. *Proc. CHI’05*. pp. 181-190.
3. Benford, S., et al. (2004) The Error of our Ways: The experience of Self-Reported Position in a Location-Based Game. *Proc. UbiComp 2004*.
4. Bogdan, C, and Severinson Eklundh, K (2004). FingerPrint: supporting social awareness in a translucent sensor-mediated cue-based environment. *CHI’04 extended abstracts*.
5. Bowers, J. (1994). The work to make a network work: studying CSCW in action. *Proc. CSCW’94*.
6. Brumitt, B, Meyers, B, Krumm, J, Kern, A, and Shafer, S. (2000). *EasyLiving: Technologies for intelligent environments*. *Proc. 2nd Int. Symposium on Handheld and Ubiquitous Computing*.
7. Button, G. & Dourish, P. (1996). Technomethodology: paradoxes and possibilities. *Proc. CHI’96*.
8. Cheverst, K, Davies, N, Mitchell, K, Friday, A, & Efstratiou, C (2000). Developing a context-aware electronic tourist guide. *Proc. CHI’00*.
9. Crabtree, A and Rodden, T (2004). Domestic routines and design for the home. *Journal of CSCW*, 13, 2.
10. Dishman, E. (2004). Inventing wellness systems for aging in place. *Computer: Innovative technology for computing professionals*. IEEE.
11. Dourish, P. (2004). What we talk about when we talk about context. *Personal and Ubiquitous Computing*.
12. Gaver, W, Bowers, J, Boucher, A, Law, A, Pennington, S and Villar N (2006). The History Tablecloth: Illuminating domestic activity. *Proc. DIS 2006*.
13. Gaver, W. (in press). Cultural Commentators: Non-Native Interpretations as Resources for Polyphonic Assessment. To appear in *IJHCI*.
14. Gaver, W, Beaver, J, and Benford, S. (2003). Ambiguity as a resource for design. *Proc. CHI’03*.
15. Meyer, S and Rakotonirainy, A (2003). A survey of research on context-aware homes. *Proc. ACSW*.
16. Picard, R. (1997). *Affective computing*. MIT Press.
17. Romero, M, Pousman, Z, Mateas, M (2006). Tableau machine: an alien presence in the home. *CHI’06 extended abstracts*, pp. 1265 – 1270.
18. Sengers, P, Liesendahl, R, Magar, W, Seibert, C, Mueller, B, Joachims, T, Geng, W, Martensson, P, Hook, K (2002). The Enigmatics of affect. *DIS ’02*.
19. Tennenbaum, D (2000). Proactive Computing. *Communications of the ACM*, May, pp. 43 – 50.