"Everybody Knows What You're Doing": A Critical Design Approach to Personal Informatics

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ABSTRACT

We present an alternative approach to the design of personal informatics systems: instead of motivating people to examine their own behaviors, this approach promotes awareness of and reflection on the infrastructures behind personal informatics and the modes of engagement that they promote. Specifically, this paper presents an interface that displays personal web browsing data. The interface aims to reveal underlying infrastructure using several methods: drawing attention to the scope of mined data by displaying deliberately selected sensitive data, using purposeful malfunction as a way to encourage reverse engineering, and challenging normative expectations around data mining by displaying information in unconventional ways. Qualitative results from a two-week deployment show that these strategies can raise people's awareness about data mining, promote efficacy and control over personal data, and inspire reflection on the goals and assumptions embedded in infrastructures for personal data analytics.

Author Keywords

Personal informatics; critical design; design strategies

ACM Classification Keywords

H.5.m. **[Information interfaces and presentation (e.g., HCI)]:** Miscellaneous.

INTRODUCTION

Users of modern technology live in an environment filled with logging technologies that gather information about them, both with and without their knowledge. Personal informatics systems invite users to reflect on and use these data, notionally to understand themselves better. The conventional approach driving personal informatics systems in the field has been self-betterment through self-knowledge: the fruits of data mining should be presented to users to promote personal optimization and self-improvement in various aspects of their lives [16].

This conventional approach to personal informatics design is facilitated by data-mining infrastructures through which data about measurable behaviors are gathered, interpreted, and reflected back to users. These infrastructures process vast amounts of personal data but often go unnoticed. Just as functioning infrastructure is embedded and transparent in regular use [24], the values of self-optimization through quantification built into these infrastructures similarly disappear into the background.

Using data for self-betterment, however, represents but one possible approach to designing personal informatics. Focusing on self-betterment may affirm and reinforce mainstream or socially predominant values, such as efficiency and optimization, at the expense of others. These systems typically present charts and graphs based on numerical information, and insights based on "the quantified self" are only one kind of insight people might seek [16]. Uncritical use of data-mining infrastructures may reinforce growing trends toward ubiquitous surveillance. Relatively few personal informatics systems encourage people to reflect on or to challenge the values embedded within them or the larger context of data mining. A number of design approaches, such as value-sensitive design [11], reflective design [22], and critical design [8], have been developed specifically to identify ways that social values are embedded in system design and to encourage consideration of alternative relationships between these systems and their users.

This paper applies critical design to personal informatics, with the goal of revealing infrastructure and engaging the users of these systems in a dialogue about the values embedded in data-mining systems. We present a set of strategies for designing personal informatics systems that draw attention to the scope and limitations of data-gathering and data-mining infrastructures. These strategies lead to the design of systems that promote an alternative to the "know thyself" rhetoric by drawing users' attention to other relationships with personal data. We demonstrate these strategies in an interface for collecting and reflecting web browsing data using text-based personal informatics visualizations embedded within the browser. To evaluate the interface and strategies, we conducted a qualitative field study in which participants used our interface for two weeks and participated in interviews about their experiences. Data from these interviews demonstrate a

number of ways that critical designs can promote reflection on and an increased critical awareness of the implications and limitations of data-mining infrastructures.

RELATED WORK
Personal Informatics and Self-Knowledge
Past research in personal informatics has shed light on the ways that users interact with and interpret their data. Most of this research has been carried out with the understanding that data-driven self-reflection can be used to help people become more aware of their own behavior [3] and change their behavior for the better [9]. These values have shaped research about the questions that individuals might ask of their data and uses for personal informatics interfaces [17].

The justification for personal informatics systems often rests on arguments about the limitations of human self knowledge: unassisted, knowing oneself is difficult because we often have incomplete data and limited ability to monitor ourselves [27]. Personal informatics augment a person's self-knowledge by breaking down human barriers to personal data management [17]. In this reading, as the infrastructures supporting ubiquitous computing continue to evolve, the promise of the field of personal informatics also grows, as increasingly rich information sources can support new levels of self-understanding and self-optimization.

In addition to the trend of gathering and analyzing more data in personal informatics interfaces, it is also becoming more common to consolidate and integrate data from a variety of sources. This tactic supports users' simultaneous exploration of multiple facets of their lives through their data [15]. As an example, popular commercial products such as Mint and Nike+ consolidate and display information from multiple data sources to help people find patterns in their financial and exercise data [17].

It is important, however, to recognize the role that the underlying value of self-optimization through self-knowledge has had in shaping the field of personal informatics. It has influenced the goals and questions of personal informatics researchers and embedded itself into the nature of data-mining infrastructure. And though there has been interest in applying personal informatics interfaces to other ends, such as reminiscing [19] and personal information management [13], there have been few studies of using personal informatics to raise awareness of the data-mining infrastructures, themselves.

Information Infrastructure and Critical Design
These infrastructures play a major role in how, what, and why people might use personal informatics. In her work on the ethnography of infrastructure, Star notes that infrastructure is, by default, "invisible, buried in semi-private settings and squirreled away in inaccessible technical code" [24]. Embedded in those systems, though, lie the socio-technical standards, aesthetics, and values of the people who build and use them. Star argues for the ethnographic examination of infrastructure, offers several dimensions of infrastructure that should be examined, and describes the feeling of "embedded strangeness" when invisible processes are brought to light [24].

Several design initiatives have sought both to make infrastructure visible and to support alternative relationships between users and the technologies that make use of such infrastructure. In critical design, Dunne and Raby have been proponents of "developing alternative and often gently provocative artifacts which set out to engage people through humor, insight, surprise and wonder" by adopting alternative values that are not typically designed for in mainstream design [8]. In their Placebo project, eight prototype objects were created with the goal of engaging users with electromagnetism through electromagnetic interference and malfunction. For example, among the objects was a table that "reminds you that electronic objects extend beyond their visible limits" by showing twenty-five compasses on its surface that twitch and spin when electronics are placed near them. They were designed to act on users' existing suspicions and elicit stories about the secret life of electronic objects as seen by their users [8]. Similarly, Redström's Chatterbox system explores various visualization techniques for reflecting on information technology use in the workplace [19].

Data visualization techniques have also been used to draw attention to power infrastructures. For instance, the *Oil Standard* modifies and augments web browsing with the tactic of revealing power and hegemony by translating the prices of consumer goods into units of oil and embedding those translations into the browser window, itself [7, 18]. In personal informatics systems, visualizations are aimed at highlighting elements of users' data, but the visualizations can also be turned on the data-mining infrastructures, themselves, to draw attention to their size and scope. For example, the Mozilla browser extension *Collusion* shows the extent to which websites cooperate to track people's behavior by visualizing cookies and the relationships among the websites that issue them [5]. By displaying the resulting network of data-mining monetization campaigns, it encourages reflection on these infrastructures.

In examining the infrastructure of personal informatics and the values and value systems embedded therein, we approach personal informatics as an arena for subjective engagement. Proponents of a subjectivist approach to personal informatics argue for balancing the presentation of objective data signals with the human ability to make sense of this information and interpret it [14]. In particular, we focus on encouraging people to playfully engage with their personal data through the idea of "making strange" [1], presenting personal informatics data in unusual ways to stimulate the values of "curiosity, play, exploration, and reflection" called for by ludic design approaches [12].

In promoting multiplicity of engagement in personal informatics interfaces, our goal is not to suggest that designing personal informatics for self-optimization
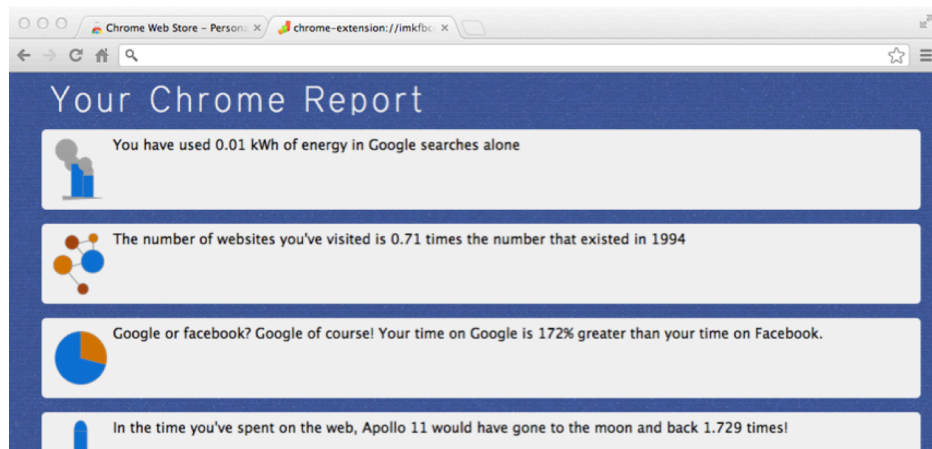
Figure 1. Screenshot of the interface.

through self knowledge is wrong; rather, it is one among a range of possibilities that can be explored. We demonstrate how raising awareness of information infrastructures is a design motivation that can challenge *and* complement personal informatics interfaces [20].

DESIGN PROCESS AND STRATEGIES

Our design goals were to raise awareness of the data-mining process, to highlight its scope and limitations, and to expose predominant values embedded in personal informatics interfaces and data-mining infrastructures. Our design process led to the articulation of three strategies, each of which addressed one of these goals.

Choosing a Data Source and Platform

We began by exploring the kinds of personal data that would be feasible to mine and would provide grist for provoking reflection. After considering potentially personal data sources such as health or biometrics information, we settled on web browsing as a data source. Web browsing activities can be highly personal, meaning that analyzing a user's browsing data both aligns with the traditional focus of personal informatics (i.e., "know thyself") and has significant provocative potential. Further, it is a kind of data that, while passively collected, is easily viewable through browsers' history listings, and it is a kind of data with known risks caused by its collection, evidenced by mass-media coverage of problems caused by the release of search histories and online identity theft.

We developed an extension to the Chrome web browser to collect browsing data and to present personal informatics visualizations of those data. Not only is Chrome a popular browser [26], but building a Chrome extension is not much more difficult or complex than building a web page, and we wanted the techniques we used to be appropriable by other designers who may not have a background in machine learning or data mining. This approach also allowed us to store and process the web browsing data on participants' machines, without having to download it to a server, allowing us to respect participants' privacy.

Creating Provocative Facts

We then examined the Chrome API to see what data it made available and how those data might be used. These available data included the URL of pages visited and the associated time stamps, with additional events for opening tabs and accessing bookmarks. This API became source material and inspiration for an extensive list of "provocative facts," specific presentations of personal information that we might be able to implement and deploy. We focused on text-based presentations rather than the graphs and charts common in conventional personal informatics interfaces, both to facilitate prototyping and to create a simple implementation that designers with other datasets could easily emulate.

We shared this list with colleagues, noting which designs provoked the strongest responses as well as the nature of those responses. The most promising designs served as templates for the final set of facts that the system presented about the users' web browsing. Opening the extension presents the user with a randomly selected subset of these facts, as shown in Figure 1.

During the implementation process, we also organized the facts into rough conceptual groups based on the nature of the provocation that they inspired. We iteratively combined, divided, and recombined these groups, along with their connections and resonances with Star's dimensions and properties of infrastructures, until each stood as both conceptually coherent and distinct from the others.

By examining the facts that ended up in each of these groups, asking what they had in common that made them provocative, and considering what sorts of discussions they evoked, we articulated a set of strategies for designing personal informatics systems. These strategies serve two roles. First, they provide concrete guidance for designers who might wish to apply critical design to the domain of personal informatics. Second, we suggest that these strategies describe an effective means for promoting critical reflection about data-mining infrastructures.

Design Strategy	Infrastructure dimension	Motivation
Make it Creepy: Display the sensitive and highly personal aspects of gathered data.	Reach or scope of data infrastructure	Raise implications of data-gathering systems for surveillance and individual privacy.
Make it Malfunction: Deliberately display gaps in gathered data	Infrastructure becomes visible upon breakdown	Promote reflection on the limitations of data gathering.
Make it Strange: Show information in unconventional ways	Infrastructure links with conventions of practice	Highlight the role of personal informatics systems in perpetuating dominant social norms in data gathering and presentation.

Table 1. Three general strategies for designing provocative facts, their relationship to Star's infrastructures, and their design goals.

Three Design Strategies

Our design strategies describe a means for achieving several goals: to raise awareness of the broad scope of personal data mining, to reveal the limitations of the data-mining process, and to expose the predominant social values embedded in personal informatics infrastructure. Table 1 presents the relationships between these strategies, Star's perspective on infrastructure, and specific design goals we hoped would help raise awareness of key aspects of data-mining infrastructures.

Make It Creepy. "Creepy" informatics highlight the scope of personal data mining and the highly personal nature of the data being collected. To make our interface creepy, we looked for personal data that might be uncomfortable for the user to confront. We did not seek data that were necessarily uncomfortable in and of themselves, but rather data that, when collected and mined, contrasts with the commonly perceived and valued anonymity of web users' behavior. For example, the fact "Did you know that we've been recording your activity for 5 days? In that time, we've seen you online for 200 total hours, and recorded more than 200 sites you've visited" calls attention to the scale and continuous nature of web data logging, as well as the extensive infrastructure that exists for gathering and manipulating users' data. The goal is not to force the user to confront uncomfortable or shameful aspects of their data, but rather to make visible the effect of being under constant surveillance, contrasting the socially normative values of logging and self-tracking with the privacy implications of personal informatics infrastructures and interfaces.

Make It Malfunction. "All models are wrong" [2], and data are always incomplete. Our second design strategy involves highlighting this incompleteness. In some ways, this strategy resonates with Chalmers' notion of "seamful design," an approach that highlights the places where ubiquitous computing technology is not perfectly seamless and explicitly incorporates such seams meaningfully into the design [4]. Similarly, "malfunctioning" informatics highlight gaps in the data and the ways that those gaps can lead to an imperfect picture of the self.

We looked for stories that seemed plausible based on the data alone, but actually were slight misinterpretations, somewhat inaccurate, or completely ridiculous. For example, the Chrome API reports how long every tab has been open but not how long it has held focus; if a user has five tabs open for one hour, a naïve reading of the data provided by the API makes it appear that the user has been online for five hours and has spent one hour on each site. This aspect of the data led to situations in which the system told the user that s/he had been online for longer than 24 hours in a single day. In another example, if the proportion of .edu websites exceeded that of other websites, users were addressed by the interface as being a "scholar." In this case, not only do many scholarly activities take place on non-edu websites, but simply visiting .edu websites does not a scholar make.

These examples show conclusions that are obviously wrong, but that wrongness is the point. By intentionally interpreting the data in incorrect or implausible ways, we engineer breakdowns that make "the normally invisible quality of working infrastructure…visible" [24]. Thus, malfunctioning informatics use satire and incorrectness to draw attention to hidden infrastructures and the assumptions made in the data-mining process.

Make It Strange. Personal informatics collect, analyze, and curate data for a specific purpose, often in the interest of persuasion or behavior change [17]. That purpose shapes the user's relationship with her or his data. Personal informatics rarely highlight the role that these interfaces play in affirming mainstream relationships between individuals and their data. Making strange informatics draws attention to the embedded norms of such systems by suggesting alternative genres of personal informatics that emphasize humor and ludic engagement over behavior change and personal optimization, while still using the metrics and vocabulary of the existing infrastructure.

Making it strange is not a matter of gamification [6] or making personal informatics "fun." Rather, it more closely resembles making fun of personal informatics. To make it strange, we followed a number of approaches. For example, one fact told the user, "You visited 592 websites this week. That's .5 times the number of webpages on the whole internet in 1994!" This historical comparison draws attention to the abundant nature of modern web browsing as collected through unique URLs, but presented in a somewhat obtuse and non-judgmental way. A similar fact stated, "In the time you've spent on the web, Apollo 11 would have gone to the moon and back 1.5 times."

Comparing the user's web browsing data with other data or known quantities measured in different units added a playful dimension, upending social convention and normative values by allowing the design to poke fun at the data or, at times, at itself.

Note that the design strategies were not explicitly described to participants, e.g., no part of the system was labeled or described as being "creepy." Rather, the strategies provide categorization, for our own design process and provide concepts that may be useful to other interested designers.

USER STUDY

To explore the potential value of our strategies, we conducted a user study to evaluate the effectiveness of each strategy at promoting critical reflection about personal informatics and their infrastructures.

Methods

We tested our interface over the course of two weeks with 23 participants, recruited using local university department listserv emails and snowball sampling from those emails. Participants received a mid-point questionnaire that asked them to talk about their experience and general use of the system, as well as their specific reactions to the responses generated by the system (e.g., which facts did you like, which did you find confusing, etc.). Participants were asked to complete an exit interview at the conclusion of the study, featuring more open-ended, interpretive questions and clarifications of responses in the mid-point questionnaire. We did an affinity analysis of our exit interview data, iteratively grouping and regrouping responses to different questions based on thematic similarity. The analysis focused on reactions such as awareness of data-mining infrastructure, criticism and rejection of the dominant personal informatics narrative, and consideration of alternative narratives and values. We used that analysis to loosely code the interviews and questionnaire responses for recurrent themes, which we organize and present in the results section below.

Results

19 (6 female) of the 23 participants returned the mid-point questionnaire and agreed to be interviewed. Our participants were mostly undergraduate students studying at a large research university in the northeastern United States. Two thirds of participants described themselves as studying in technology-oriented fields. Despite the potential bias from technology-focused students, our participant population enabled us to elicit feedback about how people reacted to the design strategies operating on their own data. It also enabled insights about how people who anticipate working in the technology sector think about the effects of designing personal informatics systems that collect and mediate data of other (often non-technical) individuals.

Analysis of our interviews revealed a consistent first impression of the interface. Participants typically saw the tool as a lighthearted and imperfect tool for introspection or—less often—a tool to contemplate one's data traces as they are seen by other online entities. The interview process often had a transformative effect. Initially, users often described the interface as being an optimization tool. After being prompted to describe their experiences of the interface, they arrived at various critical conclusions about broader privacy policy disclosure issues, the inherent limitations of data mining, and the norms and standards embedded into personal informatics. Users also recalled experiences with other personal informatics interfaces outside the traditional "self-optimization through self-knowledge" narrative. We organize the results by our three design strategies.

Make It Creepy. When asked about the scope of the data that users thought their browser collected about them, many participants "just assumed they logged everything" [P17]. 11 participants expressed awareness of and passiveness toward ubiquitous online surveillance and were not surprised about the invasive nature of the creepy informatics because "Google already knows everything about me" [P10]. When prompted to define "everything" in more detail, one user described how he imagined that Google was logging his mouse movements and keystrokes, as per his experience of using Google's built-in chat service, which "knew" whether users were idle or typing: "Chrome knows when you are sleeping, Chrome knows when you're awake…" [P3].

However, the creepy informatics prompted participants to try to identify which infrastructure recorded the number of websites visited and time spent online. One participant commented on the difference between "Chrome history, which is not to be confused with Google history… your Google search history"—where the participant explained that the latter was "going to Google" while the former was only stored locally on their computer [P12]. Participants wondered whether the data gathered in Chrome was still personally identifiable if they "don't use any Google account," and whether it was associated instead by IP address [P8]. Several participants commented on the implications of data tracking outside of our interface; one participant questioned whether Google used any identity information to affect her browsing experience:

> One thing that kind of bothers me is their personalization of your search results without them telling you […] I understand why they narrow down search results, so that people see what they want. But at the same time, it's a little strange that we can all Google the same thing and get different results…. [P10]

These later reactions demonstrate increased concern about specific aspects and implications of the data-mining process and underlying infrastructure. This attitude was also echoed by two participants who, after completing the interview, sent the researchers documents and discussions detailing Google's and Chrome's privacy policies in attempts to clarify aspects of data-mining policy. Attempts to

disambiguate the structure of personal data traces also led to critiques of the incongruity between the design motivations of the systems that gather personal data and the systems that present it back to users. When asked with whom they might share facts from our interface, users wanted to give them to other people with the intention of raising the same kinds of awareness:

> I think [my friend] would just find something like this very interesting because we have talked about these same issues before […] Oh well, everybody tracks all of your information. Everybody knows what you're doing. [P15]

Specifically, individuals who identified themselves as people with technical knowledge thought that the interface could be useful for raising awareness about data mining among non- or less-technical users:

> I would give it to a non-CS [computer science] major friend of mine, because I'd be curious in seeing how they'd respond to it… I don't think they would take the same kindness to a tool collecting statistics about them. [P16]

We hoped to use the creepy informatics to raise awareness of the scope of data mining, yet many participants expressed a general sense of complacency toward Google's ubiquitous data-mining infrastructure. However, participants speculated widely about the actual capabilities of personal informatics systems and the types of data we collected. They attempted to clarify their understanding of the personal data infrastructure, e.g., which entities had access to their information, where that information went, and the extent of the logging. Finally, users speculated on how the data-mining process affected their browsing experiences and how it might affect others' experiences.

Make It Malfunction. In response to informatics built with unreliable data, participants, understandably, did not agree with many of the representations generated in response to their behavior. In response to the system's incorrect identification of their most-visited page on Facebook (by counting time spent at a unique URL), one participant described the discrepancy:

> When I've been on Facebook, my most-visited site was the checkpoint to confirm it was you if you were using a new computer. And I've probably spent more time stalking people than just I have just pressing 'Remember this computer' or whatever. [P2]

Such reactions not only cast doubt on the rest of the interface but also prompted recounting instances of doubting other technologies:

> [On] a treadmill, even if you enter your weight and your age, it's not going to give you your exact heart rate, or…the exact number of calories burned, but you still get a sense… But the treadmill that I've been using in New York [City], I don't think it's me that's better, but it seems that I'm doing better on it than I was at home. [P4]

This reaction bounds the traditional personal informatics narrative of self-optimization through self-knowledge by recognizing that the technologies that gather data could be wrong. In particular, both knowing these limitations and having more information outside of the data presented can help people interpret the results of data mining. Presenting misinformation motivates critical discussion about the limitations of data-mining tools and their potential for error, as well as alternative roles for the user in interpreting these informatics interfaces.

15 participants also attempted to reverse-engineer the erroneous facts to explain how they were computed. This reverse engineering is a form of critical thinking where the subject disambiguates a process that would otherwise be invisible to them. One participant described a reverse-engineering process in response to a fact about her Facebook usage:

> The first time I looked at it, it said that the site on Facebook I'm most likely to visit was my friend [name]'s Facebook […] I know I've been on my own at least twice that day. So, maybe I accidentally left that tab open… and it does it by time. [P7]

Some reverse-engineering attempts were very technical, such as the participant who described his usage of the interface as "I read the analytics and then thought about which parts of my HTML headers you were collecting" [P18]. Such attention to technical detail may be due in part to our technology-heavy participant sample. However, participants from non-technical backgrounds also engaged in this reverse-engineering process:

> Unless I've discovered a wormhole, I don't see how I could have spent over 1,000 hours online in five days [...] I'm not techie at all, so I only thought of that when I got a weird answer like that. So I realized it was probably calculating all my tabs or taking all my tabs into account or something. [P11]

Such results suggest that designing misinformation can encourage reverse-engineering attempts not just for "techies," but also for people who do not describe themselves as having a technical background. These attempts lead to interrogation of a process that is often invisible or regarded as being value-neutral by non-specialists.

Finally, misinformation prompted several abstract discussions about the inherent limitations of data gathering. One participant criticized the analysis present in the interface and commented that "the same pitfalls of data mining are also true of a lot of statistical manipulation in general…. A big joke in the field is when somebody asks 'what do these numbers mean,' you say, 'what do you want them to mean?'" [P6].

Another participant asserted that web-browsing data "couldn't describe me because it only describes my browsing habits…. It just wouldn't be perfect because I

have experiences outside of the web world that would influence my web behavior" [P16]. By drawing attention to and calling into question the methods used to present the data, misinformation undermined the expectation that users are supposed to confront their data and, as a result, change their behavior. Instead, they suggested that the data could be gathered in ways that are biased and that the data presents an inherently limited subset of the users' experiences.

Thus, showing users faulty representations of their personal data provoked a variety of critical reactions about the limitations of personal informatics systems. Users responded with personal narratives around the misinformational facts and how they came into conflict with their own perceptions. Users also attempted to reverse engineer the process of the malfunctioning informatics to explain how they came to show the information that they did, and in that process demonstrated awareness of data-mining structures. More broadly, participants reflected on the effect that misinformation has on their experience of personal informatics and whether misinformation was an inherent and inevitable outcome of data-mining processes, themselves. This contentious attitude toward data-driven persuasion became more central in participants' experiences around the third strategy.

Make It Strange. Several of the facts in our interface showed data in unexpected ways. Participants referred to the strange informatics as "the random ones" and as the ones that they didn't expect to be included in the interface. Specifically, many users reported finding these facts to be unexpected because they did not present users' behavior in familiar units (such as hours or number of pages visited). Participants questioned why certain points of data were chosen and calculated in that way. In response to the fact that incorporated comparisons to the size and scope of the internet, one user looked up how many sites existed in 1994, and said in response:

> I'm actually surprised. I consider myself kind of an Internet power user, and back in 19-something-or-other… there were like ten thousand pages on the Internet, and I haven't even come close to that. [P14]

Instead of reflecting on ways to optimize his web browsing, the participant expressed being impressed by the historical size of the web.

Playful informatics drew attention to the non-neutrality of personal informatics interfaces: one participant referred to them as "sassy" [P16], and another commented that while it "seems like it's spitting out facts… it's clearly intending to get at me, somehow, and be provoking" [P4]. Several users expressed frustration toward facts that were deliberately obtuse. One fact, for example, calculated how long a user has been on their most visited site without disclosing which site it was; this fact infuriated several participants who wanted to know "where they wasted the most time" and expected our interface to show them this information. By

presenting unexpected information, we saw evidence that our strategies may have helped to uncover the expectations and standards embedded in the infrastructure.

Similarly, when a participant was asked why the system chose to show Google searches in kilowatt-hours, they added, "It's not the system, this is you!" [P13]. By making it strange, we created a space where users' expectations (the normative mainstream values of the system) fell into conflict with the interface, drawing attention to the role of the designer as a mediator of data infrastructure.

Over half of our participants responded to the ludic informatics with similarly playful appropriations. One participant proudly described his "extra browser" where he kept several tabs open and stagnant because he wanted to see how many times he "could make Apollo 11 go to the moon" [P13]. Other participants talked about "training" the interface, and doing certain superficial behaviors like closing extra tabs to get what they saw as a more favorable result from the interface (i.e., less time spent online) [P7]. One participant admitted to "fantasizing about opening all the .edu sites, so it would tell me I'm a scholar" [P3]. Similarly, participants' playful responses also extended beyond our interface to other systems, such as when a participant expressed a desire to "log one calorie" into a calorie tracker tool that predicted how much she would weigh in the future because "then it'll tell me […] you're going to weigh negative two pounds by Friday!" [P4].

One user projected her relationship to the system over time:

> I've been on Facebook for 27.83 hours, right? […] Well, I kind of don't care. Probably in another month, it telling me about how much time I spend on Facebook is just going to be kind of meaningless to me because it's like, what do those hours mean in any case? But what I do like is the one that's like you've used, mine says .03 kilowatt-hours… that and the fraction of the Internet that existed in 1994. That's kind of interesting because over time it will amount to something meaningful. [P15]

In this case, the participant dismisses the longevity of the persuasive element of personal informatics, instead adopting an alternative relationship based not on self-optimization but on a detached curiosity in watching obtuse units growing over time. These unconventional appropriations of existing infrastructure, such as logging time online in unusual units, promote long-term relationships between personal informatics and their subjects that are not part of the mainstream personal informatics narrative.

Participants' experiences and reactions to ludic informatics involved questioning the content of the interface, undertaking creative engagement, and tampering with the data-gathering infrastructure. These informatics also raised broader issues about the nature of the relationship between personal data and its subject, and the role of the designer

and the data infrastructure in forming that relationship. Ludic informatics supported alternative relationships toward personal data and prompted critical reflection on the goals and motivations of mainstream personal informatics.

DISCUSSION

The Rhetoric and Scope of Personal Informatics

Our deployment provoked discussions that problematized the "know thyself" rhetoric of personal informatics systems [16] by drawing attention to limitations to the "knowledge" that personal informatics systems can provide. These limitations were expressed in users' corrective and dismissive reactions to malfunctioning informatics, and in the acknowledgement of the incongruity between the motivations of data-gathering systems and the personal informatics interfaces that use them, as reflected by creepy informatics. Finally, as has been observed in other work around Facebook, even sophisticated and frequently used data-gathering systems can present only a part of the picture of a person's behavior [23]. Our results highlight the ways that the limitations of human self-knowledge that often motivate personal informatics are balanced by the limitations of data gathering in the informatics, themselves, and that the data presented in personal informatics systems are shaped by the infrastructures that are used to gather and present the data (as well as the fact that these data represent a subset of all possible data).

Though the "know thyself" approach has been one effective method for affecting behavior change in fields ranging from health to power usage [17], our deployment highlights a different user relationship with personal informatics systems: that the user can engage with the infrastructures underlying personal informatics by questioning the processes and the values embedded within them. Through creative tampering and dismissal of the self-optimization narrative, our interface supports ludic engagement and reflection on the values, possibilities, and limits of self-optimization.

We do not think that these alternative modes of engagement are in fundamental opposition to the "know thyself" rhetoric that dominates the personal informatics research domain; instead, we recommend that designers consider the strategies we have proposed as a method for designing and building multifaceted personal informatics systems. It is our view that these strategies can be used to complement traditional personal informatics interfaces by providing users with awareness of the underlying infrastructures and alternative ways of interpreting their outputs.

Further, just as Fogg argued that persuasive technologies bear an ethical responsibility [10], personal informatics systems may also be subject to the same ethical burden, particularly since most existing personal informatics systems have been created with the aim of persuading individual behavior change through self-reflection. Pragmatically speaking, because these systems process imperfectly collected and interpreted user data, they will always exhibit some degree of creepiness and malfunction; their output will always be framed with respect to some pre-existing set of values. Our strategies can serve as one resource for designers to acknowledge and communicate the limitations, motivations, biases, and values embedded in personal informatics systems to these systems' users [22]. In contexts in which these somewhat provocative approaches might not be appropriate for deployment in a final product, they can still exist as a design resource for encouraging designers' reflection about how to communicate the boundaries and seams in personal informatics systems that might otherwise not be visible to the systems' users.

Personal Informatics for Data Justice

Our experiences of deploying the interface also call to attention the foggy mysticism, deep uncertainties, and lack of knowledge that surround data-mining infrastructure. Like the participants in Dunne and Raby's project who heard stories of people picking up radio broadcasts in their dental filings and felt their skin tingle when they sat near a TV [8], our participants were largely aware of data mining, and many expressed concerns about its implications. However, overwhelmingly—even among technical audiences—users are unsure of exactly which processes are happening, what data are collected, where those data are stored, and what is being done with them. One participant described our interface as a form of "white-hat hacking":

> If you can log all of this stuff, then maybe just about any other Chrome extension can…. What you're doing […] is [showing] this what we could have tracked and this is what we could have possibly done with it…. It's like white-hat hacking in that way. [P13]

When we asked participants for design suggestions, they recommended changes that would facilitate understanding of the data-mining infrastructure: "There should be descriptions of where the calculations came from" [P14].

Several participants pointed out a major difference between our interface and other data-mining practices. As one participant put it, "I gave you god powers to do this because I trusted you…. I want you to show me things that I didn't opt into" [P16]. That is, our attempts to be creepy and reveal infrastructure may have been dampened by the fact that our participants "trusted us" with using their data and were fully aware of what we were doing. This is in contrast to other data-mining systems, where users are generally not fully cognizant of or complicit in the tracking of their web-browsing data. Our design strategies promote visibility of the scope of data collection carried out in data-mining infrastructures; this kind of visibility can either help to build users' trust in these infrastructures or raise important questions about where these systems might introduce risks.

Another role that an interface like ours could play, in addition to raising awareness of data mining infrastructures and opening them up for critical discussion, is to explicitly promote personal data efficacy and control. This idea is

related to work in the area of usable privacy, where concrete visualizations of personal location data over time can highlight privacy concerns compared to less revealing representations [25]. In our case, instead of describing the infrastructure in static text, interactive and personalized computations might serve as mediators between users and the infrastructure that surrounds them.

Or Not: Staying Open to Interpretation

An alternate relationship that critical personal informatics might facilitate between users and their data is that of a playful but slightly disinterested observer, one who uses the system as an object of curiosity rather than as a tool for self-mastery or data efficacy. For some users, the sense of complacency toward data mining continued after they acknowledged the extensive and poorly understood infrastructure behind the interface. Users continued to use and enjoy our system for other reasons: some users enjoyed tampering with the results, others humorously engaged with and appropriated misinformation, and still others described the joy of watching numbers grow: "I refreshed it every now and then just to see. Probably just as often as I refresh Gmail... because I'm totally a stats guy. I just like looking at numbers [...] Once I look at my numbers for long enough, they're just numbers" [P12]. Participants commented that they would enjoy the interface much less if it had a clearer persuasive agenda: "It says that I've been on Facebook for 27.83 hours…. Well, I kind of don't care" [P15].

These relationships might evolve over time. Participants described being initially surprised by the unexpected aspects of the interface, but then gradually became accustomed to it. In their interviews in *Design Noir*, Dunne and Raby asked a participant if she saw the table-shaped critical object as a kind of gadget. The participant responded that she saw it as a gadget now, but maybe if she used it enough, it would "turn into a piece of furniture" [8]. There might be a similar role for our interface: initially, it could be an instigator of data infrastructure awareness and a proponent of privacy settings, but as the radical nature wears off, it could become as much of an everyday object as the infrastructure it aims to reveal. Maybe not a kitchen table, in the sense that the interface itself is not regularly used, but as something our participants "won't uninstall… but might sporadically come back to check my favorite [data reflections]" [P11].

LIMITATIONS AND FUTURE WORK

We recognize that the reactions to our interface were specific to the audience we recruited, their age and technical capabilities, as the culture in which they live and study. While our study participants are not necessarily representative of all technology users (and did not include hard-to-reach populations), it was representative of the audience to whom traditional "quantified self" applications are generally marketed. However, as Star notes [24], things that may be visible in infrastructure for some are invisible

to others; in the future, we hope to deploy critical personal informatics to people with less technical expertise, less familiarity with data-mining techniques, and less prior exposure to personal informatics tools.

Since our approach of applying critical design techniques to personal informatics systems is relatively new, we chose to approach data gathering in an open-ended and qualitative fashion. This research approach also introduces some limitations on the kinds of data that we were able to gather. Our goal with this research was not to produce universal or generalizable findings but rather to demonstrate that the approach of applying critical design to personal informatics is a useful thing to do, and hope that future work in this field will explore different methods for evaluating the efficacy of critical personal informatics tools.

We have also taken a narrow definition of informatics: as mentioned before, our visualization is text-based, and the computations that we perform on the web-browsing data do not utilize intensive machine learning techniques. Our approach was motivated in part by feasibility—both for the researchers implementing the interface used here and for others who might use our strategies—and in part by the desire to focus our contribution on participants' engagement with our provocative design strategies and to not get distracted by the interface itself or its computational aspects (through complex data mining and pattern finding). However, we recognize that these pursuits are not antithetical to the idea of revealing infrastructure. We have suggested that perceived simplicity invites reverse engineering; further work in this area could reveal whether computational intensity promotes higher or lower levels of critical engagement.

We hope that our design strategies could be used in conjunction with traditional personal informatics approaches to draw users' attention to the processes of data collection and data presentation, as well as the implications and limitations of those processes. Because we intended our strategies to be generalizable, we are continuing to explore their applicability both to different contexts, such as with health and emotion data. We are also interested in combining personal data sets across different settings, and a breadth of "personal" data, such as data shared among several people or, even more broadly, across social and political networks.

CONCLUSION

Personal informatics represents a significant class of applications built atop ubiquitous data-gathering and data-mining infrastructures. While these systems have the potential to allow people to reflect on their own behaviors and habits, existing systems do a poor job of communicating the scope of data collected to build models of human activity, owning up to the errors possible when making sense of mined data, or explicitly acknowledging the values embedded in decisions about which data are collected and how they are reflected back to the user.

In this paper, we argue for the role of critical design in challenging the status quo of personal informatics. We present three design strategies that encourage outward reflection on the data-mining infrastructures and personal informatics interfaces, themselves—as well as the kinds of relationships that these technologies typically afford—by suggesting the possibility of alternative relationships between personal data and its subjects. Our approach challenges the designers of personal informatics systems to incorporate representations of their systems' limitations by foregrounding their potential creepiness, their potential for malfunctions, and the strangeness revealed when systems embody values different from those prescribed by mainstream systems. An analysis of how users experienced a system built around these provocative strategies affirms that personal informatics systems can be used to raise awareness about data mining, can promote efficacy and control over personal data, and can also challenge the role of data analytics as persuasive agents.

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