

# Seeing the Invisible

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**Abstract.** In this article we attempt a closer examination of the notion of invisibility as it has been used within the ubiquitous computing community. We seek to tease apart the various metaphorical understandings of invisibility as emergent attributes of technology use, examining what true ‘invisible technology’ might be, in what ways it is beneficial, and how it might be designed for. We propose a theoretical model consisting of two complementary concepts: invisibility-in-use, the experience of direct interaction with artifacts and tools largely free of conscious monitoring, and infrastructural invisibility, the capacity of physical, organizational, or technological infrastructures to become tacit in the thoughts of actions of human actors. Underlying our approach is the belief that invisibility is fundamentally a phenomenological human construct, an experience of being in the world that is socially and psychologically created by humans as they go about their various activities.

## 1 Introduction

The last decade has witnessed the emergence of ubiquitous computing, a research effort seeking to make technology “disappear,” for it to become “invisible,” or “fade into the background.” Some researchers try to address these goals more or less literally, embedding computation into the environment and attempting to make human-computer interaction less apparent and more “calm” and “natural.” Other researchers treat this metaphorically, talking about designing technologies that fade into our conceptual background, the goal being the construction of tools that we work through rather than work with. Still others conflate both these approaches.

Mark Weiser [13] referred to invisible technology as that which is “so imbedded, so fitting, so natural, that we use it without even thinking about it.” Satyanarayanan [9] interprets invisibility as “complete disappearance of pervasive computing technology from a user’s consciousness.” Fishkin, Moran, and Harrison [3] envision “a progression towards a more real-world interaction style, where there is no perceived mediation, i.e., an invisible user interface.” Norman [7] writes “The computer is really an infrastructure, even though today we treat it as the end object. Infrastructures should be invisible ... A user-centered, human-centered humane technology where today’s personal computer has disappeared into invisibility.”

While in many ways inspiring, these concepts, when taken in aggregate, are ripe with inconsistency. There is a distinct aesthetic appeal to rendering systems physically invisible, but total invisibility, and the lack of feedback and control that implies, is obviously undesirable. From the psychological perspective, designing calm or ubiquitous technologies is clearly a valuable goal, but just what factors are involved in creating such systems are often not elaborated – many times it seems assumed that these invisible technologies will be amenable to a simple walk-up-and-use paradigm. Presumably these technologies will leverage our tacit knowledge<sup>1</sup>, but it is unclear how much consideration has been given to the nature and sources of such knowledge.

In this paper we first address why invisibility is a worthy topic of consideration for the design of interactive technologies and begin the process of clarifying the topic by outlining specifically what we think invisibility is **not**. We then identify and explore in further depth two forms of invisibility that lie at the heart of the ubiquitous computing agenda: invisibility-in-use, in which we are “freed to use technologies without thinking and so to focus beyond them on new goals,” and infrastructural invisibility, “everywhere computing that does not live on a personal device of any sort, but is in the woodwork everywhere.” Underlying our approach is the belief that invisibility is fundamentally a phenomenological human construct, an experience of being in the world that is socially and psychologically created by humans as they go about their various activities. As such, our approach is rooted in phenomenological philosophy, including the works of Heidegger [4] and Merleau-Ponty [6], as popularized within human-computer interaction by authors such as Suchman [11] and Dourish [2]. The results of these investigations are then synthesized in the form of implications for the design of ubiquitous computing systems. Finally, we conclude with a summary and contemplate the appropriate role of invisibility within ubiquitous computing.

## 1.1 What Invisibility is Not

The discussion of invisibility is obfuscated by different perspectives of the term. It should be stated that the concept of invisible interfaces does not in any way imply literal physical invisibility, as pointed out by Tolmie et al [12]. Such an approach would eliminate the control and feedback mechanisms that are at the heart of good user interface design. Instead, judicious design of appropriate feedback and affordances for further inspection and control are needed. The design challenge is to achieve this without unduly overwhelming or unnecessarily distracting users. At the same time, true phenomenological invisibility, a socially and psychologically constructed experience, cannot be designed into a system. As such, it can be facilitated by design, but its actual achievement is a construct of the human mind, influenced by numerous contextual factors. This implies that the goal of design should not be walk up and use systems.

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<sup>1</sup> Tacit knowledge: our knowledge and abilities that enter into the production of behaviors and/or the constitution of mental states but are not ordinarily accessible to consciousness. (Adapted from the Dictionary of Philosophy of Mind, <http://www.artsci.wustl.edu/~philos/MindDict/>)

## **2 *Invisibility-In-Use***

Ranging from pencils to computers, invisibility-in-use refers to the phenomena in which people directly employ tools or concepts without consciously monitoring them; when people work *through* their tools rather than *with* them. Inherent in this explication is a phenomenological account of tool use. These notions have been the object of philosophical and psychological study as least as early as Heidegger's *Being and Time* [4], in which Heidegger uses the terms *zuhanden* (ready-to-hand) and *vorhanden* (present-at-hand) to describe the unconscious and conscious use of tools. The relevance of these concepts to Human-Computer Interaction has been elaborated in works by both Winograd and Flores [14] and Dourish [2]. Dourish gives an example of the two by relating it to computer mouse use: when the mouse is used to complete some task, it becomes an extension of the body and we use it unconsciously. However, as soon as the mouse runs off the pad or the wire obstructs motion, it is present-at-hand, or arises in our consciousness and we are aware of it, no longer working through it.

### **2.1 Studying Invisibility-In-Use**

An emerging framework with which to study invisibility-in-use can be drawn from existing HCI disciplines such as Distributed Cognitions [8], but valuable insight can also be gained from the psychology of flow [1] and relevant literature in expertise [5]. As ubiquitous computing involves interaction with multiple devices, objects, and other people, holistic psychological frameworks such as distributed cognition will undoubtedly prove useful. In addition, the psychology of flow might better elucidate the loss of conscious attention that is central to invisibility-in-use and the psychology of expertise can make clear how invisibility-in-use arises as a result of learning and practice.

## **3 *Infrastructural Invisibility***

Computation is already an infrastructural service. The average computer user, whether she is surfing the web, editing a spreadsheet, or playing a 3D video game is rarely thinking in terms of electrons, logic gates, or machine instructions—computation is effectively invisible. Continuing along these lines, a primary aim of ubicomp is to better infrastructuralize ever higher-level computing services, moving them out of the desktop and directly into more diverse and immediate contexts of use. Yet the challenges of building effectively invisible infrastructures, especially on the grand scale envisioned by futurists and ubicomp researchers alike, have social and psychological as well as technical aspects, all of which are inextricably interrelated.

By infrastructural invisibility we mean the capacity for infrastructure, whether physical, technological, or organizational, to become tacit in thought and action for human users. Creating such infrastructures is not just a function of technological design and engineering feasibility. Standardization bodies, negotiation, and (often

implicit) categorization structures are all part of crafting an infrastructure. Infrastructures are never completed works, but living, evolving bodies requiring regular maintenance and development. Furthermore, infrastructure and its effects must be adequately understood and leveraged by those within its sphere of influence if it is to be of benefit to society, let alone invisible.

### **3.1 Studying Infrastructural Invisibility**

While historical analysis can unearth larger trends and events, qualitative fieldwork seems particularly attractive as a means for unearthing the invisible in infrastructure use. Though the use of ethnography and observed long-term deployment are well known to the HCI community, infrastructure presents some unique challenges worth considering. S. L. Star considers some of the methodological issues in studying infrastructure [10]. Of note is the problem of scale. Ethnographic practices can provide the level of qualitative results necessary to reveal the mundane and largely invisible interactions with infrastructure that occur, but infrastructural use and development also occurs at a much larger scale, across peoples, organizations, and disparate geographical locations. While logging technologies can collect a wealth of observational data, tried and true techniques for reducing this data into useful, manageable collections have yet to emerge. In light of these difficulties, Star presents some tips for the infrastructural ethnographer, including identifying master narratives embedded in the infrastructure and surfacing “hidden” work (e.g., the influence of secretaries in the publishing practices of scientists).

## **4 Conclusion**

These proposed strategies are intentionally vague and general; it is largely through the continued experiences of designers and users that we will refine the design process. At this point in time, a rigid scientific account of the invisible eludes us, and will continue to do so for the foreseeable future. Still, the continuing confluence of psychology and neuroscience and the sustained efforts of concerned social scientists will undoubtedly unearth new understandings relevant to the issues that concern us. We conclude, then, not with a laundry list of items for future work (though there be many), but by speculating about the appropriateness of invisibility as the goal of the ubiquitous computing research program. As presented here, invisibility is primarily an experienced relationship between humans and their tools, whether they are physical or conceptual. Within this relationship there is no inherent value judgment—the tool may be a creative instrument, or it may be a weapon. However, both implicit and explicit in the rhetoric of ubicomp is the creation of technologies that benefit society, both in measurable form and through aesthetic enrichment. It often seems that this idea has become largely bound up in the notion of the invisible. Invisibility itself is amoral, and can be achieved just as readily in the context of detrimental or immoral action. Rather, it is through the achievement of invisibility in the context of beneficial actions—beneficial independent of invisibility—that ubicomp hopes to improve the

quality of life of its users. If the ubiquitous computing field, either through design or inertia, wishes to redefine invisibility in such a manner, so be it. Let us make sure, however, that we are explicit about it—that we see what we are doing.

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