

When Users “Do” the UbiComp

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Computers have become ubiquitous, but in a different way than envisioned in the 1990s. To master the present-day ubiComp—a multilayered agglomeration of connections and data, distributed physically and digitally, and operating under no recognizable guiding principles—the user must exhibit foresight, cunning, and perseverance. Preoccupation with Weiserian visions of ubiComp may have diverted HCI research toward problems that do not meet the day-to-day needs of developers.

The Two UbiComps

Ubiquitous computing can be viewed from two distinct perspectives. On the one hand there is the avant-garde that gets presented in scientific conferences and follows Mark Weiser's and others' visions on context awareness, beyond-GUI interfaces, and new networking techniques. On the other, present-day IT infrastructure, “the real ubiComp,” is a massive noncentralized agglomeration of the devices, connectivity and electricity means, applications, services, and interfaces, as well as material objects such as cables and meeting rooms and support surfaces that have emerged almost anarchistically, without a recognized set of guiding principles. This infrastructure is not homogenous or seamless, but fragmented into several techniques that the user has to study and use. These

techniques typically connect only two devices or applications at a time. This form of ubiComp is not embedded in the environment, but its logic is affected by remote factors often opaque to the user, such as servers, and by other people.

In their paper, entitled provocatively “Yesterday's Tomorrows,” Bell and Dourish lamented that “ubiComp has turned out to be characterized by improvisation and appropriation; by technologies lashed together and maintained in synch only through considerable efforts; by surprising appropriations of technology for purposes never imagined by their inventors [1].” The image in Figure 1 is an example of what those look like in their best (or worst).

It may be that complexity of the existing ubiComp is one key explanation to why ubiComp applications have not conquered the consumer market, although more than a decade of research has produced numerous should-be-convincing demonstrations. According to a keynote speech at MobileHCI 2006, Nokia lost \$4.5 billion in a year because of product returns and complaints, of which approximately 20 percent was caused by problems attributable to usability and complexity.

Yet the bulk of empirical studies looking at ubiComp at an extra-application level has been close to nonexistent, aris-

ing only recently. To mention a few, Mainwaring and colleagues studied the things urbanites carry with them and how these things are perceived to “interface” with the urban environment [2]. Woodruff and colleagues examined temporal patterns of using a laptop at home [3]. Our own study of mobile information workers at Nokia's internal IT division, reported in Oulasvirta and Sumari [4], explains some of the tactics and discipline people develop and the ensuing burden when working with multiple portable and nonportable computing devices. These articles show many ways in which it is the users who have to “do” ubiComp; that is, actively create the resources for using an application in a heterogeneous, multicomputer environment.

A Study of Computer Jugglers

To explain what is behind these dramatic-sounding claims, let us revisit observations from one of the aforementioned studies [4]. Eleven workers, all extreme users to whom ubiComp means both the content and means of work, were interviewed and observed. In their daily pursuits, much of what is wrong about ubiComp became visible.

All workers had multiple devices to choose from: at least a smartphone plus a laptop, and a mobile phone, as well as various necessary accessories such

[1] Bell, G., and P. Dourish, “Yesterday's tomorrows: Notes on ubiquitous computing's dominant vision.” *Personal and Ubiquitous Computing* 11, no. 2 (2006): 133-143.

[2] Mainwaring, S.D., Anderson, K., and Chang, M.F. Living for the global city: Mobile kits, urban interfaces, and ubiComp. In *Proc. UbiComp'05*, Springer (2005): 268-286.

[3] Woodruff, A., Anderson, A., Mainwaring, S.D., and Aipperspach, R. Portable, but not mobile: A study of wireless laptops in the home. In *Proc. Pervasive'07*, Springer (2007): 216-233.

[4] Oulasvirta, A., and Sumari, L. Mobile kits and laptop trays: Managing multiple devices in mobile information work. In *Proc. CHI'07*, ACM Press (2007): 1127-1136.

as docking stations, chargers, headsets, cables, etc. In their work situations, and when moving between them, the workers switched the primary device they used quite often. There were even “frenzies” where this kind of juggling took place at intervals of less than five minutes. The workers actually perceived many benefits for having multiple devices instead of just one: more suitable display and manipulation mechanisms to choose from, reducing the time and effort needed to set up a device, being able to multitask, having devices as backup storages of data, improving personal “ergonomics,” choosing devices that are socially more acceptable, improving privacy, and securing company-sensitive data.

However, they were not able to achieve these feats easily—considerable effort, improvisation, and knowledge were needed. The main problems did not relate as much to the interconnection and operation of devices in situ, but to three things that we discuss below: 1) “being context-aware,” i.e., actively creating resources from what is available for using a computer; 2) “achieving seamlessness,” i.e., ensuring access to necessary data across situations and devices; and 3) “doing nondisruptiveness,” i.e., being able to gracefully align the use of computers with the physical,



► **Figure 1.** Present-day ubicomp: the desk of a designer at the Royal College of Arts.

cognitive, and social demands of the situation at hand.

Being Context-Aware

Pre-trip planning is a nodal moment where beliefs about infrastructure become visible. There, a user must choose what devices to bring along and how to prepare them. The workers’ strategies of choosing devices ranged from conservative—always taking the same set of devices along—to opportunistic—taking devices “just in case”—to planned—planning the use of devices for each day or trip.

In the two strategies mentioned last, users exhibited being somewhat knowledgeable of which resources will be available and which not. The decision to take devices was accompanied by a variety of concerns—the battery life, wireless connectivity, or social acceptability in the future site of use.

Workers also exhibited perceptual skills used to see oppor-

tunities in the surrounding environment to transform it for use. Figure 2 shows such “context-awareness.” While waiting for a meeting to start, the worker made room for the use of his laptop by clearing the support surface of a beverage trolley.

The present-day ubicomp does not automatically adjust its provided resources according to users’ situations. Rather, it is the users who have to anticipate, search for, and plug into the computational resources, and for that they need knowledge of the upcoming situations and skill to adjust their own behavior accordingly.

Achieving Seamlessness

The notion of information access “anywhere, anytime” has been argued to be mainly a rhetorical notion [5]. Users are not really capable or even interested in having information available everywhere.

Trying to achieve “anytime, anywhere” when operating in

[5] Perry, M., O’Hara, K., Sellen, A., Brown, B., and Harper, R. Dealing with mobility: Understanding access anytime, anywhere. *ACM Transactions on Computer-Human Interaction (TOCHI)* 8, 4 (2001), 323-347.



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► **Figure 2.** Using a laptop on the corner of a beverage trolley [4].

the present-day multidevice environment implies having additional tasks of transferring operation and data across devices and places. For this, users must be conscious of the various technological “seams” working counter to their goals, such as discontinuities in connectivity or electricity.

The workers exhibited intricate knowledge of the supportive and constraining factors particularly in local and frequently visited places. For other kinds of trips they had to choose strategies that addressed uncertainty over possible seams.

Some workers used server backups that they knew they could access in a place with a wireless connection. When anticipation was not possible or desired due to cognitive cost, users disciplined themselves to take backups of important files on their smartphone, for example, when going on a longer trip. If, for some reason, the laptop

was not available, a product presentation would then be available from the smartphone. Such “just in case” backup devices were taken along also on shorter trips within the office, where there was a possibility of encountering an important colleague.

The workers also employed a variety of strategies to share documents between their devices. Each device provides different affordances to access information, and users were sensitive to those. Some users did “data mirroring,” copying files to the smartphone for read only. Two-way synchronization, updating file versions on each device after each update, was the most laborious strategy as it required its adopter to discipline herself to do it, for example, in the mornings. When upcoming situations were predictable, a worker could get by with opportunistic synchronization of a single device.

Some workers accepted the risk of not having certain information conveniently accessible in all situations. By dedicating certain documents exclusively to certain devices, they could avoid synchronization work.

Interestingly, these strategies of distributing data between devices go hand-in-hand with physical demands and impediments, and vice versa. A superior strategy in carrying one's mobile devices may be poor as it requires excess synchronization. We reported on the users' "mobile kits," i.e., keeping the repertoire of things carried fixed [2]. While having a more or less static kit reduces cognitive effort, it does so with the cost of manual labor, time, and physical effort stemming from the burden of packing, maintaining, and carrying the kit.

Weiser warned against "making everything the same," to which aiming for seamlessness would lead. Instead, we should design "beautiful seams" and seams that can be appropriated [6]. The present-day ubicomp, unfortunately, is not there yet. The seams are not visible and certainly not beautiful. The disconnected and fragmented technological resources must be known in advance, planned and prepared for. The nature of seams is not only a problem of the digital but they are also inherently linked to the way we structure our action and share efforts to tasks of physical nature, such as carrying devices.

Doing Nondisruptiveness

The final point concerns nondisruptiveness. Followers of Weiser's vision have referred to concepts like calmness, ambi-

ence, and invisibility as design drivers. The user should be able to peacefully concentrate on the task at hand and not disrupt others.

On the positive side, the workers were indeed able to use devices nondisruptively; or, at least, they did not problematize it. On the negative side, it was not because of devices' clever design but because of new habits they acquired. Some learned how to set up their devices only one small step at a time in the beginning of meetings so that they could appear to be concentrating on the meeting, not on the laptop. To streamline the transition of computing state from one meeting to another, one worker had adopted the habit of closing the laptop lid but leaving the computer running and piling all auxiliaries on the top surface. Some workers thought that others perceive working on a bigger laptop while in a meeting as less disrupting than working on a smaller-screen smartphone that demands less attention.

Similarly to context-awareness and seamlessness, making choices that determine disruptiveness is a task left to the users.

Toward Fluent Multidevice Work

Imagination is open for ideas on design. In the paper we presented what was basically a laundry list of approaches to improving ubicomp infrastructures: 1) minimizing overheads that create temporal seams between activities; 2) making remote but important resources, such as connectivity or cables, better transparent locally and

digitally; 3) propagating meta-data on migration of data from device to device; 4) supporting ad hoc uses of proximate devices' resources like projectors, keyboards, and displays; 5) triggering digital events like synchronization of predetermined documents with physical gestures; and 6) supporting appropriation of material properties for support surfaces. Users essentially need new and more efficient ways to interoperate devices, plan action in the face of "seams," understand and manage technological complexity, plug their data into other devices, and align use fluently with everyday activities.

The drifting apart of HCI research and real-world ubicomp is worrisome because improving the state of affairs is not the duty of engineers alone. Ethnographers and user researchers can contribute to the efforts in improving ubicomp by studying practices that construct and keep it together [7].

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