

# Ubiquitous Computing

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The idea behind ubiquitous computing is to surround ourselves with computers and software that are carefully tuned to offer us unobtrusive assistance as we navigate through our work and personal lives. Contrast this with the world of computers as we know them now. Some are very obtrusive—remember the car that called out, "Door is ajar… Door is ajar…" until someone finally kicked the door shut? Others attempt to offer assistance but deliver only frustration, like that new Web camera's automatic installation routine that didn't *quite* perform all of the configuration necessary—and didn't offer any guidance on what else needed to be done.

We are caught in an interesting trap. On one hand, we are beguiled by the promise of greater productivity and convenience. On the other, we are frustrated by tools that are brittle and unintuitive. Though much software is easier to use than ever, it feels as though we are far from the science fiction dream of unobtrusive computers that let us work naturally and that operate as seamless extensions of our personal work styles. There is hope, however. The ubiquitous computing movement is focused on this seemingly distant vision and may help us achieve the greater productivity that sits with it on the horizon.

We'll start our discussion by reviewing the technology and themes underlying ubiquitous computing. We'll then describe a vision of how these may play out in the workplace, followed by some implications we see for I-O psychology. Finally, for readers interested in delving deeper into the world of ubiquitous computing, we will list some resources offering additional information.

## Ubiquitous Computing: The Basics

Ubiquitous computing (often abbreviated to "ubicomp") refers to a new genre of computing in which the computer completely permeates the life of the user. In ubiquitous computing, computers become a helpful but invisible force, assisting the user in meeting his or her needs without getting in the way.

On his Web site (http://www.ubiq.com/hypertext/weiser/UbiHome.html), Xerox PARC's Mark Weiser, the originator of the term "ubiquitous computing," described it this way: "… [Ubiquitous computing's] highest ideal is to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it."

### *Nanotechnology and Wireless Technology*

If computers are to be everywhere, unobtrusive, and truly helpful, they must be as small as possible and capable of communicating between themselves. Technological movements supporting these goals are already well underway under the rubrics *nanotechnology* and *wireless computing*.

#### *Nanotechnology*

The trend toward miniaturization of computer components down to an atomic scale is known as nanotechnology. Nanotechnology involves building highly miniaturized computers from individual atoms or molecules acting as transistors, which are the heart of the computer chip. The number of transistors in a chip is indicative of its power. Therefore, nanotechnology's extreme miniaturization of transistors allows for impressive levels of computing power to be put into tiny packages, which can then be unobtrusively tucked away.

#### *Wireless Computing*

Wireless computing refers to the use of wireless technology to connect computers to a network. Wireless computing is so attractive because it allows workers to escape the tether of a network cable and access network and communication services from anywhere within reach of a wireless network. Wireless computing has attracted enormous market interest, as witnessed by consumer demand for wireless home networks, which can be purchased for several hundred dollars. The second author has a three-computer wireless network in his home.

### *Context-Awareness and Natural Interaction*

Small computers that communicate wirelessly provide a necessary infrastructure for ubiquitous computing. However, infrastructure is only half of the battle. As noted above, the ubiquitous computing movement aims to make computers more helpful and easier to use. Indeed, computers should be able to accurately anticipate the user's needs and accommodate his or her natural communication modes and styles. These themes are captured with-

in the ubiquitous computing movement's focus on context-aware computing and natural interaction.

### *Context-Awareness*

The promise of context-awareness is that computers will be able to understand enough of a user's current situation to offer services, resources, or information relevant to the particular context. The attributes of context to a particular situation vary widely, and may include the user's location, current role (mother, daughter, office manager, soccer coach, etc.), past activity, and affective state. Beyond the user, context may include the current date and time, and other objects and people in the environment. The application of context may include any combination of these elements. For example, a context-aware map might use the information that the user is away from home, has no appointments, and that the time is 6:00 in the evening to determine that the user could soon be interested in dinner. It would then prepare to offer the user guidance to nearby restaurants should he or she make such a request.

### *Natural Interaction*

Currently, using the computer is part of the task we are attempting to accomplish—something else to focus on, learn, or do in order to accomplish a goal. The idea behind natural interaction is for the computer to supply services, resources, or information to a user without the user having to think about the rules of how to use the computer to get them. In this way, the user is not preoccupied with the dual tasks of using the computer *and* getting the services, resources, or information. Donald Norman, a well-known researcher in human–computer interaction, once said that he doesn't want a word processor; he wants a letter writer—something that will allow him to get the job done of writing a letter, without the instrument getting in the way.

## The Promise of Ubiquitous Computing in the Workplace

The elements of ubiquitous computing—nanotechnology, wireless computing, context-awareness, and natural interaction—offer a powerful set of tools to achieve the promise of ubiquitous computing. To provide a better sense of what this future holds, let's take a look at how ubiquitous computing might play out in the workplace.

### *The Desk Job*

It's the beginning of the day and Elaine has a major presentation to work on for a sales call. Two weeks ago, when the meeting was set up, she instructed her calendar to schedule two additional meetings with her team to

prepare for the presentation. It is about time for the second meeting, and she walks into the conference room that her calendar had reserved. The display on the conference room door lists the title of the meeting and checks off attendees as they enter. The giant "workboard" on one wall of the room has preloaded all of the documents related to the presentation and is waiting for input. When everybody has arrived for the meeting, the display on the conference room door lists the meeting as "in progress" and dims the window to minimize distraction from the busy hallway outside.

As the team reviews the presentation, Elaine spots a section that flows poorly. After discussing it with the team, she calls to the workboard and tells it to move the section on product features to just before the section on optional services. The meeting covers several additional topics and then disbands 10 minutes early. The workboard automatically saves the updated files as the attendees exit the room.

On the way back to her desk, Elaine stops by her friend Roger's desk to ask him a question. Sensing her approach, Roger's computer works in the background to load documents that the two of them have worked on together in the past 2 weeks, should any of them be required. Elaine is greeted excitedly by Roger, who is rushing to a meeting of his own. "We really need your input on pricing for this service," says Roger. "Can you join us?" Elaine can spare some time, so she elects to participate in the meeting.

When Elaine enters the conference room, her calendar automatically updates to include the new meeting. After Roger introduces the topic, Elaine says, "My team came up with a template to determine pricing for a slightly different service. Maybe we can use it as a starting point." Elaine approaches the workboard, and a list of her public files appears. The files are sorted in alphabetical order, with the files whose contents are related to the topic of the meeting highlighted. Elaine touches the template file, and the document opens. After some discussion, the template is modified and is ready for testing. Meeting attendees pitch different "what-if" scenarios, which are automatically entered into the template and processed, with the final price displayed. Once everyone is satisfied with the revised template, the meeting breaks up.

To thank Elaine for her help, Roger offers to buy her lunch at the cafeteria. Elaine accepts the invitation, saying that she'll be ready as soon as she checks her video mail. As she approaches a nearby public communications portal, the screen shows the four new video mails waiting for her. One video mail is from a longstanding client. She touches the message and watches as the client recounts a story of superior service received from one of Elaine's direct reports, Dave. Elaine tells the video mail system to add the message to her file on Dave, and records a thank-you message to the client. Business done, Elaine and Roger take the elevator down to the cafeteria.

## Implications for I-O Psychology

Though Elaine's workplace sounds very attractive, the question remains as to what ubiquitous computing will mean to I-O psychology. We see two major implications. First, ubiquitous computing will change the workplace that serves as our subject matter. The workplace described above doesn't seem all that different from a modern office setting—more streamlined, certainly, but still recognizable. This is because we had great difficulty imagining how a future working environment might differ radically from our own. Yet, as we know, technology can enact quick changes to the workplace and make it look very different, very quickly. As I-O psychologists, we must recognize these changes and form strategies to address them as they affect our mission.

A second implication we see is in the promise ubiquitous computing holds to enable new approaches to I-O psychology. The core themes of ubiquitous computing, natural interaction and context-awareness, clearly offer a lot of power for us to harness. Examples are easy to generate—a quick brainstorm led to ideas that spanned a number of core I-O activities. Rather than present a laundry list of ideas, we will propose just one, a fictional just-in-time training system called "UbiquiTrain," and develop it in some detail.

## *UbiquiTrain*

The UbiquiTrain system is based on a database of training content to which users connect via desktop computers and wireless handheld systems. UbiquiTrain loads training content according to an algorithm that includes a number of context-related cues. The first cue centers on the user's schedule. For example, if there is an upcoming meeting called by the user, UbiquiTrain would load training content on how to lead meetings. As the meeting time approaches, this training content floats to the top of the list of topics available. A second cue invokes the context of the user's current activities. If the user is working on a task related to an item on his or her to-do list, UbiquiTrain would load corresponding content, as well. For example, the user working on a proposal would cue UbiquiTrain to call up training content on written communication in general and proposal writing in particular. UbiquiTrain holds content at the ready should users ask for it. The system does not demand the user's attention.

As befits the nature of ubiquitous computing, users interact with UbiquiTrain in the way that feels most natural to them. Some users talk to the system, asking it to show them a particular piece of training content. Others, not yet comfortable with talking to a computer, use the touch screen. UbiquiTrain reacts to the user, as well. Noting the confusion on the user's face as it explains how to deal with attendees who derail meetings, for exam-

ple, UbiquiTrain tries explaining the concept a different way. It then offers a short video example. Observing that the user is nodding, UbiquiTrain resumes the normal course of training. Of course, if users are looking for information on a particular topic, they can skip straight to the content simply by asking for it. UbiquiTrain is flexible enough to understand the different ways users might request a given piece of content.

UbiquiTrain is more than a means to deliver already-developed training content. The system also offers important benefits in training needs assessment by monitoring trends in training content demands across users. The system takes action when it senses a trend in demand for certain broad areas of training content among members of particular departments or among workers with similar duties across different departments. As a means of respecting users' privacy, the system polls them and asks if they would like to request in-depth training on the topic, taking suggestions for areas in which users might want particular detail. If sufficient interest is found, the results are then forwarded to the group responsible for training in the organization. By observing trends in content demand, UbiquiTrain can also sense when its database is incomplete. If users ask for content that doesn't exist in the database, the request is logged. If a sufficient number of similar requests are received, the system generates a requisition for new content. In this way, the database stays current with the needs of its users.

Finally, UbiquiTrain can help evaluate the training it has delivered. The most overt way is to ask the user for feedback on the training received. A second way is have the user request relevant coworkers to evaluate him or her in a given area at a given time, if appropriate. The rating task, of course, is administered by UbiquiTrain through the coworkers' computers or handhelds. Raters can choose to make their ratings and comments anonymous, if they wish. Once all of the data are compiled, UbiquiTrain feeds them back to the user and offers appropriate development suggestions. The system makes use of the data, as well, to track the effectiveness of the training it has delivered.

Clearly, UbiquiTrain offers important benefits to all constituents. Users have a convenient, up-to-date training tool that unobtrusively responds to their needs. At the corporate level, the training needs within the organization are easily tracked and clearly delineated and can be analyzed to fine detail. Ubiquitous computing serves I-O psychology very nicely, indeed.

## Concerns

The power ubiquitous computing promises carries with it significant risks. One such risk is associated with the amount of privacy that must be sacrificed to see the benefits of truly helpful computers. Another is that

early, "bleeding edge" applications of ubiquitous computing will turn out to be more ambitious than effective, leading some to prematurely conclude that the idea is a failure. We address each of these concerns below.

### *Privacy Issues*

Simply put, the more software tracks users, the more opportunities exist to trample on their right to privacy. To some degree, these issues are already being argued in the contexts of corporate e-mail snooping and the use of IT software that can track user activity down to the level of individual keystrokes. However, factoring in the idea of software that can track and act upon a user's physical presence and form of activity leads to privacy concerns of a magnitude beyond those currently debated. The privacy implications of ubiquitous computing implementations must always be accorded the most careful consideration. Without powerful standards surrounding user privacy, the future world of ubiquitous computing may very well shift from one of ease and convenience to one where each of us has an inescapable sense of being watched, at best, and no control over our personal information, at worst. Such prospects are clearly far from desirable.

### *Growing Pains*

Systems that can act as subtly as those described will not come without a substantial developer learning curve. As system developers learn from their mistakes, there will undoubtedly be at least one premature declaration that truly ubiquitous computing is an impractical ideal and that the interim efforts are too riddled with problems to be usable. We cannot guarantee that ubiquitous computing will fulfill its promise. However, we would argue that it *ought* to do so, based on the strong trend we have observed toward more powerful, more usable software. The first author recalls a word processor from about 1984 that required the manual entry of printer codes for boldface and italic fonts. Advanced ideas like templates and styles—and, come to think of it, tables—were far from consideration as features. Modern word processors are very powerful, flexible, and easy to use compared to anything that has come before. Usability is definitely a recognized goal in software design, and much has been learned to make new software—even unique, new applications—very easy to use. It should only get better.

## Final Thoughts

The promise of ubiquitous computing is of a life in which our endeavors are powerfully, though subtly, assisted by computers. The idealistic visions painted by the ubiquitous computing movement stand in stark contrast to what we see when we boot up our computers each day. There is an immediate barrier because you have to know how to use a computer to use a com-

puter. If you sat down in front of a computer without knowing how to use a mouse, would you be able to get anything done? It's unlikely. The computer won't help you, either, since you have to know how to use the computer to ask it for help on how to use it! When computers do offer assistance, it still tends to fall short of the mark. Much application software tries to cater to new users and power users alike by offering simple, task-focused "wizards" and detailed help systems. Unfortunately, the wizards are often too limited to offer sufficient power for day-to-day use, and the help systems often don't cope well with the many ways in which a user can express a need for a given piece of information. The next step, of course, is to go down to the local bookstore and buy a book that is four inches thick and weighs five pounds and that promises to give straightforward instruction on how to use the program in question. Most of us get by just fine on the tasks we are well-used to performing. However, there *should* be an easier route.

We are still a long way away from seeing the promise of ubiquitous computing fulfilled. Yet, physical barriers to ubiquitous computing are falling, thanks to technological advances such as nanotechnology and wireless computing. Further, as we have argued, software is getting easier to use all the time. As the themes of context-awareness and natural interaction are adopted by hardware and software makers, we will begin to see successive approximations of ubiquitous computing. There are many issues to resolve and a steep learning curve to face as we consider this close integration of computers into our lives. As I-O psychologists, we will benefit ourselves and our field by carefully examining the promises and implications that ubiquitous computing holds for us, and then adapting our products, services, and policies appropriately.

## Suggested Readings


Abowd, G.D., & Mynatt, E.D. (March, 2000). Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction, 7,* pp. 29–58.

Bergman, E. (2000). *Information appliances and beyond*. San Francisco: Morgan Kauffman.

Stanton, N.A. (Ed.). (2001). Ubiquitous computing: Anytime, anyplace, anywhere? [Special Issue]. *International Journal of Human-Computer Interaction, 14* (4).

Weiser, M. (1991, September). The computer for the 21st century. *Scientific American, 265,* 94–104.


Note: The authors have compiled a folder of links to ubiquitous computing-related Web sites. Please e-mail Jason Weiss at Jason.Weiss@ddiworld.com if you would like these links forwarded you.

## Authors' Notes


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## A Word About Leading Edge

This is the first article in a regular column I am writing on advances in technology that hold promise for I-O psychology. I see these articles as a sort of successor to the **Traveling in Cyberspace** columns written by Philip Craiger, with my occasional assistance. **Traveling in Cyberspace** began in 1995, around the time of the popular emergence of the World Wide Web. We had just put *TIP* and SIOP on the Web, and we were eager to write about the ways in which we saw the Web transforming work processes.

Since then, the Web has gone from a nifty idea with lots of potential ("Check it out…You can *hyperlink* to other documents!") to a backbone supporting a multitude of business processes. More relevant to our purposes, the Web has made significant inroads on many aspects of our work as I-O psychologists and sits at the heart of many of the services we deliver. It's amazing to look back a mere 7 years and consider both how far the technology has advanced and how crucial it is to us now.

For all that, the Web is only the latest technological tool to find an appreciative audience. Other technologies currently in development promise additional, powerful benefits. That's where this column comes in: My goal is to explore significant new technologies that hold promise for I-O psychology. This promise could be fulfilled by improving research and practice, by helping us be more personally productive, or by some other means entirely. By bringing these technologies to light, I hope to spark further discussion on how we can harness them and, perhaps, even some efforts to adopt these technologies and start realizing the gains they hold in store.

If there is a particular technology you would like to see discussed, or if you would like to talk in greater depth about anything already covered, I encourage you to e-mail me at Jason.Weiss@ddiworld.com.