

Usability and Self-Service Information Technology: Cognitive Engineering in Product Design and Evaluation

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Self-service products such as automatic teller machines are becoming more complex as they support new services, are being used in new environments, and employ new technologies. End-users' expectations of self-service products also are being raised as they gain more experience with interactive technologies. This paper describes the cognitive engineering activities of self-service information technology, including end-user perceptions, performance, and satisfaction. Such issues as specifying usability at concept stages, integrating prototype evaluations, and incorporating design recommendations also are discussed. In addition, the paper presents practical methods to design self-service products, including heuristic usability evaluations, "Wizard of Oz" investigations, and formal task-based evaluations. The paper also draws upon a number of usability studies conducted by self-service product and advanced technology developers.

Introduction

The ubiquitous automatic teller machine (ATM) is a very important part of daily banking for most people and is critical to banking operations, since upwards of 75 percent of all cash transactions in the United Kingdom and the United States are carried out by these self-service terminals. While, from the user's point of view, inserting a magnetic card into a self-service terminal and keying in a few commands is ostensibly rather simple to perform, designing in this simplicity of use is very challenging, requiring the use of complex mechanical, electronic, software, and communications technologies.

These terminals are no longer confined to the basic function of dispensing cash but span complex retail bank transactions, ranging from check and bill imaging to multimedia and remote video-mediated assistance. As can be imagined, the variety of consumers who use ATMs is great, as is the range of environments in which ATMs are located and the tasks that they can perform.

Cognitive Engineering. One crucial technology in developing self-service products is the field of *cognitive engineering*, also referred to as *usability engineering* and *human factors engineering*. Cognitive engineering is generally understood to mean the study of human interaction with devices and systems. Its goal is to ensure that people can carry out interactive tasks easily, effectively, and in a satisfying manner. Today, workers in post-industrialized economies typically encounter products and systems that make mental demands on them, rather than physical demands, especially as we see the spread and acceptance of computer-based technology in all walks of life.

Contemporary cognitive engineers are dealing with these issues within multidisciplinary teams developing products and services. Their role in the development effort is to deal with user needs, highlighting current user difficulties and ensuring that products, systems, and services will succeed because they are based on appropriate user-centered

design. The applied discipline of cognitive engineering leans heavily on the knowledge and methods developed by human experimental psychology and, to a lesser extent, on applied physiology and related human sciences.

In this paper, we first introduce some of the applicable research in cognitive engineering, and then briefly describe the processes and facilities employed by cognitive engineering at AT&T Global Information Solutions (AT&T-GIS) in Scotland. The body of the paper concentrates on examples of recent work, introducing the range of methods and the scope of activity undertaken in support of user-centered self-service information technology (IT). The paper concludes with an outline of plans for the future, and a note on the lessons learned in the application and integration of cognitive engineering in the AT&T-GIS development organization.

This paper focuses primarily on ATMs, although the principles and techniques discussed are applicable to the development of any product or service. ATM user issues are addressed in AT&T-GIS in a variety of areas, including:

- Basic anthropometric analyses, that is, the study of a user's position, reach, and posture in using an ATM;
- The use of ATMs by people with special needs;
- The gathering of user attitudes towards biometrics recognition devices, which permit a system to verify the identity of a user by, for example, a fingerprint or voice print;
- User acceptance and the integration of new devices into products and services, and
- The development of contemporary user interfaces.

Previous Research. AT&T-GIS is building upon the growing recognition, within AT&T and elsewhere, that ease of use is critical to the commercial success of services and products.¹⁻⁴

Usability and human factors research into ATMs has, to date, looked at users' mental models,⁵—that is, how people generally conceive of the content and working of ATMs; their general usability;⁶ and various adoption and acceptance issues in the use of ATMs for banking.^{7,8}

Within AT&T-GIS, we also have carried out ATM-related investigations into end-users' mental conceptual models.⁹ The company also has examined evaluation methods appropriate to self-service products.¹⁰ However, unlike, say, the domain of telephony, the self-service ter-

Panel 1. Abbreviations, Acronyms, and Terms

ATM — Automatic teller machine
GIS — AT&T Global Information Solutions
HCI — human-computer interaction
ISO — International Organization for Standardization
HTA — hierarchical task analysis
IT — information technology
PDA — personal digital assistant
SVHS — super video home system
UTT — usability technology team

minal as a walk-up-and-use product has received relatively little attention from either the human-computer interaction (HCI) or cognitive engineering communities. Our usability work within the development of self-service solutions for the financial sector is beginning to redress this imbalance.

Cognitive Engineering in AT&T-GIS

Awareness of cognitive engineering has increased considerably throughout AT&T-GIS, including product development. This section reviews the current state of cognitive engineering at AT&T-GIS, including resources, process issues, and cognitive engineering facilities.

AT&T-GIS in Scotland is a leader in self-service technology, with development and manufacturing facilities in Dundee and St. Davids. In the self-service marketplace, AT&T-GIS holds 27 percent of the world market and exports to 103 countries. The company has received ISO 9001 and "Tick IT" certification, and was awarded the 1994 Scottish Engineering Award and the 1995 Queen's Award for Export Achievement.

A drive initiated by AT&T-GIS Corporate Cognitive Engineering, a core group of cognitive engineers located in Atlanta, Georgia, has led to the introduction of usability specialists in many development organizations, including industrial design, where they focus their work around a common user-centered design theme. As the number of full-time cognitive engineers has grown, they have expanded their alliances with leading usability and design organizations to sup-

port their work.¹¹ They have developed increasingly important links with their U.S. counterparts in AT&T, particularly within AT&T Bell Laboratories, and have employed several external subcontractors in the United Kingdom and the United States. They also have been supported by internships.

For AT&T-GIS, cognitive engineering is more than HCI or workplace ergonomics. It is, instead, an umbrella for all user-related concerns and their solutions. To coordinate usability activities throughout the AT&T-GIS Financial Systems Group, which develops ATM machines, a usability technology team (UTT) has been established that represents AT&T-GIS development sites in Waterloo in Ontario, Canada; Dayton, Ohio; and Dundee and St. Davids in Scotland. This team functions as a forum for design and usability issues, and helps define the direction and strategy, chiefly for advanced development projects.

Process Issues at AT&T-GIS

As mentioned earlier, cognitive engineering works closely with industrial design in the development of self-service terminals. The ISO-9001-accredited development, supply, and manufacturing operations at Dundee and St. Davids in Scotland are governed by specified processes, which are continually improved as a fundamental part of the ISO philosophy. Efforts are underway to further improve development and specific engineering processes by including a more user-centered focus, from the earliest product conception through post-release evaluation.

Driven by cognitive engineering, the emphasis here is to:

- Analyze end-user requirements at the initial design stages,
- Define these requirements as usability specifications,
- Design iteratively using appropriate prototyping approaches, and
- Carry out thorough user trials.

Many usability evaluation activities have been integrated within product development planning. We are currently refining versions of a process that will affect all major stages of self-service product development, based on research findings of discrete user needs, usability specifications, and accumulative evaluations.

The lessons learned thus far relate mostly to the

need for flexibility when deciding on which methods to use in determining and evaluating user requirements. Given the variety possible in feature, product, and system development, it is prudent not to be too specific in determining which methodologies should be employed at certain phases. Rather, it is better to specify the boundaries and necessary outcomes, leaving the cognitive engineers some latitude in selecting the proper methods and testing innovative approaches.

Usability Facilities at AT&T-GIS

The development of usability laboratories has been a particularly fruitful tool. We have recently equipped a primary laboratory at the AT&T-GIS St. Davids site, and are developing a second facility at Dundee. These laboratories, together with appropriate "field-kit" evaluations, enable us to meet the growing number of requests for usability support, chiefly user-based evaluations of development prototypes and competitors' products.

The St. David's Laboratory follows a standard contemporary set-up. The laboratory consists of two adjoining rooms, one dedicated to the observation of users, the other a control and analysis room. Product and system users are observed by a system of cameras, microphones, and recorders. The laboratory uses super VHS format (S-VHS) recording equipment with digital editing and analysis facilities. The design and implementation of the laboratory has been heavily influenced by precursors within AT&T-GIS¹² and current practices within the usability engineering community.¹³

While acknowledging the increased popularity of predominantly field-based approaches to understand the use of products and systems,¹⁴ usability laboratories still remain a cornerstone of applied cognitive engineering.

Together with the appropriate development processes, laboratory studies help predict and deal with specific usability problems during product development. Such a laboratory also provides an extremely powerful tool to identify and publicize general usability issues that affect overall product use.

Usability and Self-Service IT Development

This section describes cognitive engineering work within two important areas of the Dundee organization: technology development and ATM development. The

Table I. Users' perceptions of privacy using a speech-based ATM.

Condition	Handset	ATM-mounted stem microphone
Canopy/cover on ATM	4.5	4.8
No canopy/cover on ATM	5	5

examples illustrate the range of usability activities supporting self-service IT development.

Usability Activities in Technology Development. The Dundee-based Technology Development Group assesses future technologies and the skills a user would be required to have for the Financial Systems Group of AT&T-GIS. The Dundee group also plays an important role in supporting feasibility projects, such as assessing user acceptance of a new service or feature. This group also supports usability initiatives—such as the UTT—throughout the whole Financial Systems Group.

Self-service interfaces. Projects within the Technology Development Group have covered such topics as user reactions to voice verification technologies at the self-service interface¹⁵ and the study of adaptive self-service interfaces. Typically, Technology Development Group projects identify the information and expertise needed for someone to use a product in advance of formal development. Technology teams, such as the UTT, are the primary channel for receiving such requests and for the subsequent dissemination of project findings.

Biometrics recognition. Much of the usability work in recent years has been to investigate field-based end-user reactions towards new biometrics recognition technologies. Such technologies permit a system to verify that individuals, such as card-holders in a self-service scenario, are exactly who they say they are.

Privacy issues. Another investigation focused upon the issue of privacy when using a speech-based ATM transaction. Four experimental conditions were devised. Two variables involved whether a microphone was positioned within a conventional telephone handset or within a flexible stem extending out from the ATM. The other two variables involved whether or not the ATM was located in an integrated booth.

The results, shown in Table I, indicated few differences between these variables in terms of a user's perceived privacy during a transaction. Participants indicated their agreement of the statement "I felt that others could

overhear me when I used the machine," with 1 indicating "strongly disagree" to 5 indicating "strongly agree."

Personal digital assistant. The use of portable, hand-held devices as a means of carrying out daily banking chores also has been a focus of attention. The personal digital assistant (PDA) already has many uses within computing and may well play a significant role in the future of consumer banking, particularly with the increasing use of smart cards. Usability studies in this area^{16,17} have highlighted some non-trivial HCI factors such as the comfort of pen-type input devices, the need for simple menu structures, accessible input touch areas, ease of navigation, clear design of icons, and appropriate and customizable functionality.

Such investigations also permit usability techniques themselves to be evaluated for effectiveness. In the case of the PDA evaluations, we were concerned with the effectiveness of our experimental and heuristic techniques, but found our results closely aligned with the findings of other human factors specialists dealing with more conventional products.¹⁸

User perceptions. Perceptions of self-service technology determine which problems some users experience in using public terminals such as ATMs. For instance, while investigating the use of ATMs from the perspective of older adults, we have discovered that actual experience is the prime factor in predicting the ease with which the user can use a technology. When other factors are looked at in isolation—such as age, gender, disability status, education, work status, and income—they don't account for significant variations in ease of use. These figures are based upon a survey of 4,500 adults in U.S. metropolitan areas.

Furthermore, novel introductions to the self-service transaction—for example, the use of thermal paper to print out receipts—have to be fully understood before embarking upon complete developments. For the end user, the introduction of such a technology may have implications for the perceived quality of service, speed of

the transaction, and reduced auditory feedback.

Adaptive menus. For many self-service consumers, ease of use means quickly reaching certain services and avoiding others. Thus, systems should have a degree of "intelligence" and adapt their menus via short cuts for experienced users.

The Technology Development Group has undertaken usability studies to examine the influence of adaptive systems on users' attitudes and behavior, comparing situations in which users are either aware or unaware of the system's purpose. Such studies reveal important data on consumer attitudes, and provide knowledge essential for the development of more advanced, and more complex, products and systems.

The studies of new self-service technologies involve both laboratory and field settings, including detailed observation, the development of appropriate questionnaires and interview checklists, and the occasional use of consumer focus groups.

Usability Activities in ATM Development. This section looks at some of the ways usability issues are tackled in the development of specific self-service products, in this case ATMs. As off-premises non-branch locations such as supermarkets and shopping centers become increasingly important to our customers, we have sought to offer optimum solutions, tailored to the specific needs of the environment, task, and user.

New technology. The usability evaluation work carried out on the 5670 ATM, a single-function ATM targeted at off-premises locations, has considered both the high- and low-level goals in the overall design (see Figure 1). For example, general access for people with special needs and the precise form of the swipe card reader represent issues at the high- and low-levels, respectively.

One version of the 5670 uses a swipe card reader to initiate a transaction, rather than the type that "ingests" the card for the duration of the transaction. The usability investigations of an ATM-mounted swipe card reader were conducted for different physical forms, orientations, and positioning on the face of the machine.

In this case, the findings of cognitive engineering have influenced the design of the swipe reader, the design of the swipe reader's graphic prompts to the user, and its positioning on the ATM. Extensive video recordings of end-users, subjective responses, error rates, and the number of correct readings of the data on the card were the

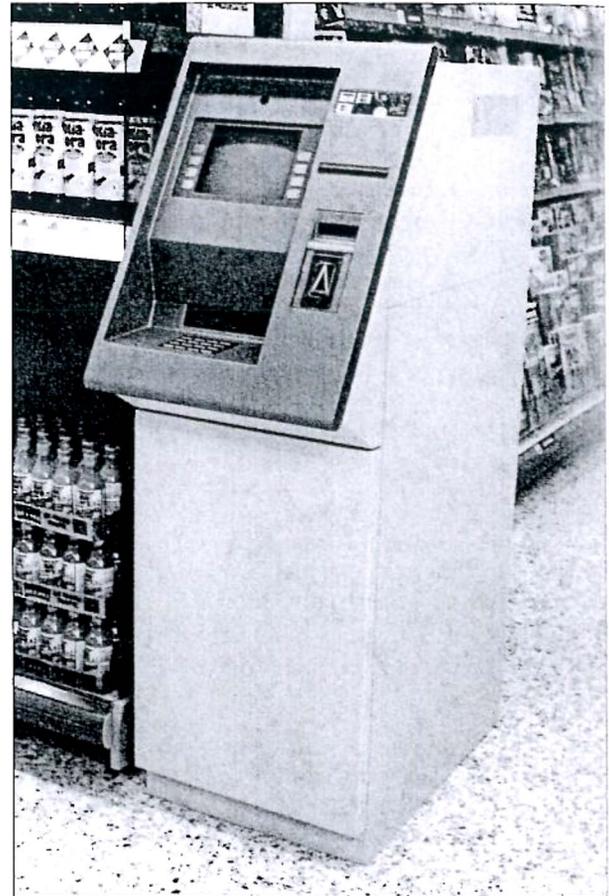


Figure 1. Usability evaluation work was carried out on AT&T-GIS's 5670 ATM, a single-function ATM designed for off-premises locations such as supermarkets.

main factors in reaching the final design decisions.

Accessibility. Much ATM usability evaluation work has focused on the issue of consumer accessibility—for example, how a user must reach to get the transaction statement from a behind-the-fascia printer—while the user either is standing or in a wheelchair at either lobby or through-the-wall ATM's. Bear in mind that self-service terminals are used in more than 100 countries by a great variety of users. Focus on access, heights, and depth of reach is due to ever-changing user preferences, industry

Table II. Service engineering task analysis.

Standard completion time (minutes)	Actual completion time (minutes)	Task description, completion status	Postural difficulties	Exposure time	Engineer rating on task ease
30.0	28.5	Card reader removal and replacement	<ul style="list-style-type: none">• Back bent• One limb below shoulder level• Loading on one leg only, leg bent	60 seconds, repeated 4 times during maintenance	3.0

standards, and government legislation. All access studies must, therefore, incorporate balanced experimental designs and appropriate task selection and measures to accommodate a wide range of consumers.

Serviceability. Obviously, the consumer represents only one type of user. Broadly, there are three main end-user groups:

- Consumers, who use the terminal to withdraw cash or receive account information;
- Replenishers and balancers, often a combined function carried out by a bank's staff, with some very basic maintenance responsibilities; and
- Service engineers, dealing with detailed terminal maintenance, upgrading, and repair.

The terminals also must be installed, overseen, and supervised within a computerized network, adding the usability issues of these specialists to our concerns.

One area of impact on usability engineering is serviceability—for example, how easy it is for service engineers to repair both front- and rear-access ATM products.

Service engineering investigations have looked at two major issues:

- Evaluation of the minimum service footprint, the area around the ATM that must be left clear for service engineers to make repairs, and
- Investigation into the general serviceability of internal modules.

Both these issues were analyzed by determining how repair personnel work, the time it takes them to complete a task, and the footprint needed based on actual experience in the field. This early work also shed light on some of the "pet hates" of maintenance engineers and replenishment staff. This data was shared later during design sessions for future products.

Postural analysis. A more specific indication of ease of serviceability is postural analysis using what is known as the OWAS posture set.^{19,20} OWAS provides a means of

categorizing body positions, coupled with information from questionnaires and the measurement of task completion times, that can be compared to a known mean. Table II provides an illustration of the types of data collected from such studies.

The postures of service engineers and product assemblers were studied, according to their dynamic and static stress level—that is, stress associated with body movement or a held, fixed position—against the time it took to perform a specific task. As a result, specific design changes were made and the size of the minimum service footprint for rear access was increased by 250 percent (see Figure 2). The results of this study are to be incorporated into the design of new products.

Serviceability research, recently embodied within the usability engineering process, is fast becoming the prime focus of hardware ergonomics within AT&T-GIS at Dundee.

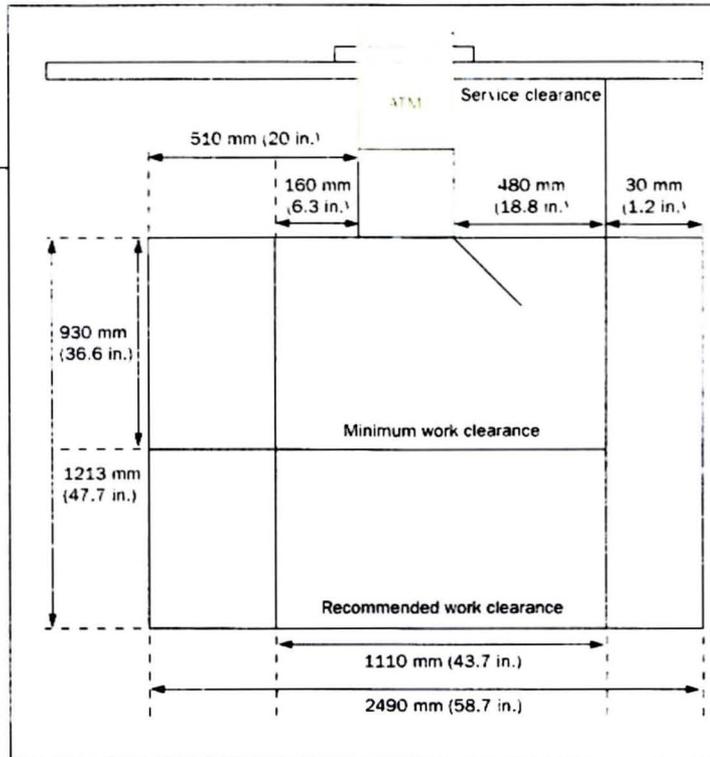
Software usability. Increasingly important is the software controlling, monitoring, and reporting on the status of the self-service terminal. One such software tool, called State of Health, helps an ATM operator replenish and balance the machine. By using hierarchical task analysis (HTA) of everyday operations²¹ and determining user requirements, areas for further improvement can be identified (see Figure 3).

Interviews with a number of customer maintenance personnel regarding the day-to-day running of the system provided specific recommendations on the configuration of the new design and helped validate the existing system structure.

The graphical interface now being developed draws heavily upon the information derived from these studies. When completed, the interface will be prototyped and evaluated by customers prior to empirical task-based evaluation work and final design iterations.

Another area of research concerns the soft-

Figure 2. As a result of usability studies of maintenance functions, specific design changes were made and the size of the minimum service footprint for rear access was increased by 250 percent.



ware tools with which developers can produce applications to run on self-service terminals. Developing tools for these applications are necessarily sophisticated and broad in terms of functionality. Recent work has concentrated on a new product that is object-oriented, presenting, in contrast to previous tools, a graphical user interface. An evaluation by users in Europe and the U.S. of the design of icon sets in a functioning prototype provided valuable and timely feedback to the software developers. Issues such as system navigation and the status of system elements were found to be crucial in the overall ease of use of the product.

Development projects in the area of self-service network management also are being supported by usability engineering, providing assistance in the evaluation of alternative user interface concepts and early prototypes.

Employing usability engineering from the early project requirements and planning stage, also called the scoping stage,²² has increased the developers' confidence in the design of new products—from external fascia design to internal hardware engineering.

Usability Methods In Self-Service IT

The success of usability engineering in self-service IT depends to a large extent upon the flexibility of approaches and the user-centered methods that are

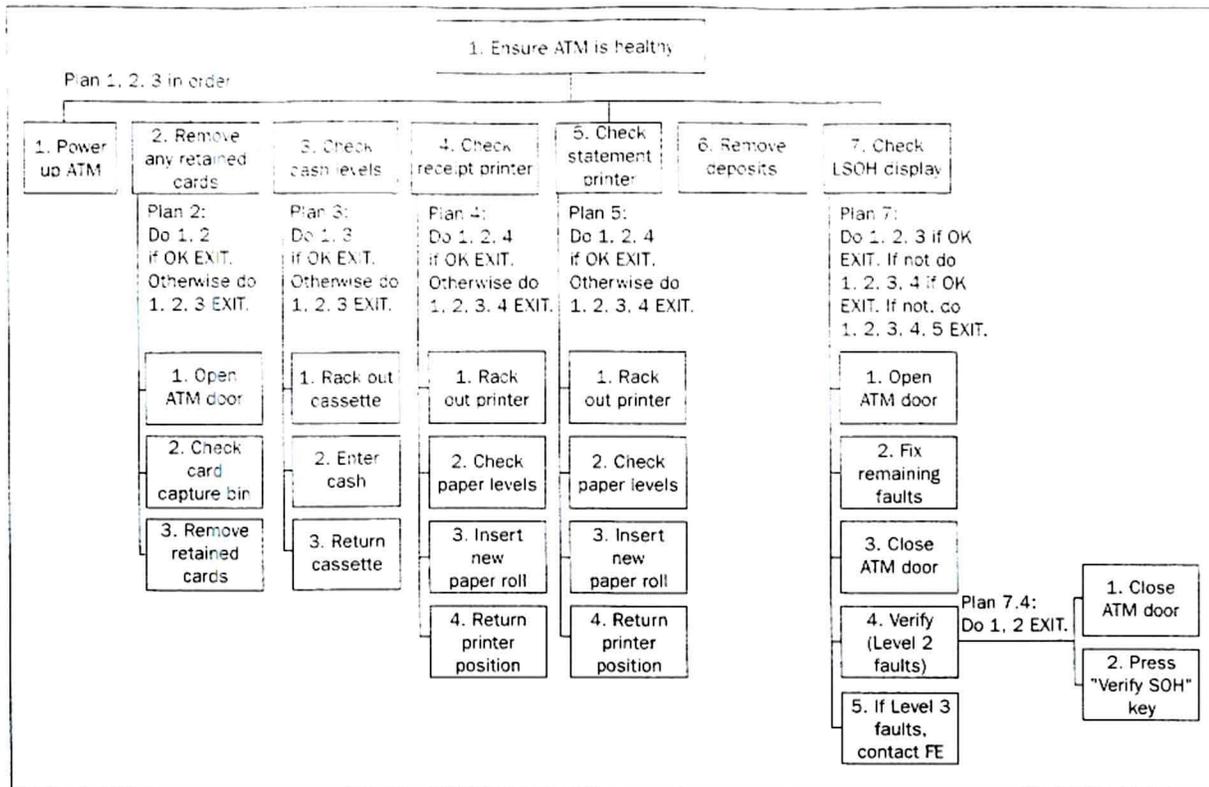
inherent in such approaches. Within product development, the regular use of quantitative and qualitative techniques, user-based evaluations, checklists, and heuristic evaluations^{16,23-25} of design iterations often depend upon schedule and resource requirements and constraints.¹⁷

In other cases, where the usability questions may be broader, focus groups and user surveys can play a significant role during earlier stages of development.

Also, where fully-functioning prototypes may be unavailable, "Wizard of Oz"²⁶ approaches can help in understanding and solving user difficulties. One "Wizard of Oz" investigation employed a non-functioning prototype. To simulate a working machine, a "wizard"—an actor performing the necessary ATM functions without the user's knowledge—prompted the user, manually changed screens, accepted cards and deposits, dispensed cash, and provided receipts.

The test allowed realistic user behavior to be studied at a very early stage, before commitments were made to the initial design. The evaluations, which included users in wheelchairs, resulted in a radically redesigned cash dispenser and an improved monitor angle.

Putting together usability specifications grounded in user requirements and task analysis are the essential starting points for any cognitive engineering work with product development, be it software or hardware design.²⁷



It is then incumbent upon the cognitive engineer to follow these up with usability testing throughout the development program.

Finally, assessments must be made of self-service IT as it is deployed in the field, to benchmark and provide data to future development. In all, a pluralistic perspective of methodology, in which we view the end-users' experiences as a whole, helps guide the adoption and development of appropriate techniques.

Lessons Learned and Future Challenges

Some of the most important lessons learned have been in the area of results, communication, and process. The use of a cross-site technology team chartered with the coordination of usability activities, such as the UTT, has proved to be valuable in learning project needs and disseminating research results.

In the same vein, the pilot activities conducted within "usability awareness" courses for developers have proved a success, providing developers a grounding in the basics of usability engineering and user-centered design, and providing an opportunity to examine the local implications for particular groups and their approach to development.

The issue of user-centered processes and their integration also has been shown to be of great importance. Wherever possible we are consolidating these

Figure 3. By using the hierarchical task analysis (HTA) of everyday operations²¹ and determining user requirements, areas for improving ATM functionality can be identified.

processes as a means of ensuring appropriate usability engineering roles throughout development.

Finally, the use of external, sub-contracted organizations for assistance with major usability engineering is initially attractive, but the need to retain and build upon in-house expertise is clear. In the long term, in-house resource development should reduce dependence upon external support.

Conclusion

This paper has presented a brief overview of usability engineering at AT&T-GIS in Dundee. It is evident that the standing of this discipline has increased dramatically over recent years, both with customers and competitors. With the introduction of usability laboratories and the support from the whole organization, the growth of cognitive engineering within AT&T-GIS in Scotland will continue.

The recent introduction to development of user-centered design procedures ensures that the success stories associated with usability engineering will continue. From advanced development projects examining, for

instance, psychological factors underlying consumer reactions and expectations, to schedule-bound user-centered evaluations of prototypes, the work continues to grow in both scope and visibility.

The message from the various activities within self-service product development is clear: The users, their experiences, needs, and expectations are central to good product and system design, which, in turn, is clearly linked to the commercial success of our products.

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