DESIGNING THE HUMAN INTERFACE: AN OVERVIEW

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This issue of the *AT&T Technical Journal* focuses on the role of human factors in user-interface design. This article provides an overview of the contribution of human factors specialists to the design and evaluation of user interfaces and of user-interface technologies for AT&T products and services. It introduces each of the other articles in this issue within the context of ongoing human factors activity at AT&T.

Introduction

AT&T's success in the telecommunications market has always been based on providing customers with products and services that meet their needs. Alexander Graham Bell and Thomas Watson's creation of a usable device for transmitting the voice over wire was rooted in Bell's commitment to improving communication for people who were deaf. In addition, Bell's study of the physiology of human speech and hearing was critical to his invention of the telephone. Thus, in his work, Bell studied not only technology, but also the capacities of potential *users* of his invention. In today's competitive marketplace, the goal of meeting real human needs is more important than ever. Accomplishing this goal requires, as it did in the day of Alexander Graham Bell, understanding human capabilities as well as technological possibilities. Study of the capabilities and needs of users of a product or service and application of this knowledge to the design of products and services is known as *human factors*.

Human factors has had a long and successful history of contributing to telecommunications design at Bell Laboratories. Hanson provides an excellent summary of this history in a 1983 issue of *The Bell System Technical Journal* devoted to human factors and behavioral science.[1] As Hanson noted, human factors decisions were made about telephones from the beginning of telephony. The initial challenge was to improve the quality and intelligibility of transmitted speech. Then in the 1920s and 1930s, the physical dimensions of customers' hands and heads and the properties of the human ear and voice were studied to improve the design of telephone sets. In the mid-1940s, when Bell Laboratories added a User Preference Research department, the focus of human factors work was extended to include network applications and user preferences for alternative designs. Throughout the next 40

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years, human factors work continued to expand both in focus and in the organizations within which it was represented.

Today at AT&T, human factors work contributes to a broad variety of products, services, and technologies. Human factors specialists continue to contribute to the design of user interfaces for telephones, focusing on physical design, ringing signals, visual indicators, software-based features, and voice quality. In addition, human factors work has expanded to include rapidly developing technologies (such as graphical workstations, text-to-speech synthesis, and automatic speech recognition) and the products that incorporate these technologies.

The goal of human factors work is to optimize the performance of an entire system, where the system includes both the human being and the technological tool the human is using to facilitate his or her work. To meet this goal, products and services must be designed so that (a) they match the abilities of the people who use them and (b) they are appropriate for the tasks people will perform with them. When products are so designed, they are safe, easy to learn, and easy to use; they minimize errors, increase productivity, and, ideally, are even fun to use. These factors contribute significantly to a customer's perception of the quality of a product. [The term "products" is used throughout this article to refer to products, services, and user-interface technologies (such as speech recognition or graphical displays) that are incorporated into products and services.]

The primary focus of human factors work is on the *user interface* of a product. This includes any component of a product with which the human, the user, comes into contact. It includes, for example, terminal hardware (lights, buttons, keyboards), operational procedures and associated user feedback (such as tones or light flashes), computer-user dialogues and computer screen designs, synthetic voice prompts and feedback, user manuals, and user training procedures. In addition, one branch of human factors activity considers the organizational context and social structure into which new technology is placed; a broad overview of this work is provided by Pava.[2]

The final user interface of a product results, of course, from a team effort. The team often includes specialists from many disciplines, including marketing, systems engineering, computer science, electrical and mechanical engineering, operations research, and graphics design. Human factors specialists play a unique role on such a team, ensuring that the abilities and needs of the user are carefully considered as the product—and especially the user interface—is being designed.

Human factors specialists are typically trained in experimental psychology or some other area of behavioral science (e.g., linguistics or sociology). These specialists, thus, bring two important types of knowledge to the design process:
- Knowledge of human abilities and limitations
- Knowledge of empirical methods for collecting valid data from humans and skills in interpreting such data.

The knowledge of human abilities and limitations is based on the research literature in numerous areas of experimental psychology, including cognition (memory, reasoning, problem-solving, decision-making), learning, human performance, visual and auditory perception, psycholinguistics, motivation, and physical strength and skills. Because products must be matched to the abilities of potential users, this knowledge is critical in the design process. A simple example is basing the physical design of a telephone handset on the modal distance between a human's ear and mouth. A more complex example is the design of a graphical user interface, which would build on a knowledge of:
- *Perceptual skills*, such as which visual objects are easily discriminable and how information should be presented for easy identification of the most critical objects.
- *Motor skills*, such as how large an area is needed for selection with a mouse.
- *Cognitive skills*, such as what operational procedures are easy to learn and to remember across all the tasks for which the interface is being designed.

In addition to a knowledge of human abilities,

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human factors specialists have experience using a variety of empirical methods for collecting and interpreting information from humans. These methods include experimental design, statistical data analysis techniques, observational techniques for use in the laboratory and the field, focus group techniques, and survey techniques. These methods primarily help a designer obtain *valid* and *reliable* information from users or potential users. It is easy to collect information from people, especially information that confirms what we expect to find. Unfortunately, it is not as easy to collect unbiased information that can be generalized to a large population of users. The empirical methods of behavioral scientists have been developed to collect unbiased, generalizable information. Thus, they allow us to obtain evaluations of products or technologies from the *perspective of the user*. These evaluations can then be used to improve the user interfaces of products throughout the product realization process, resulting in a final product that the user judges to be useful and of high quality.

Quality and the User Interface

The user interface contributes significantly to the user's perception of the quality of a product. The value of a feature depends, to a great extent, on a person's ability to actually use that feature. Imagine a telephone system with a myriad of features, including hold, conferencing, call forwarding, and calling party identification. Imagine, however, that a user cannot remember the rather complex means for using these features and cannot find instructions easily in a user's manual. For this user, these features might as well *not* exist.

There are many examples of such products in the marketplace, products in which features are provided but are too complex to use. Few things are more frustrating to a user than being unable to access and use a feature provided by a system. Unusable features contribute to a perception of poor quality. Conversely, easily used features make a strong, positive statement about quality. It is not surprising that "user friendly" has become a popular term for advertisers and the public.

Consumers expect and demand that they be able to use a tool to facilitate their work, rather than having to work harder to learn how to use a tool. When competing products provide the same features, it is likely that the products will be differentiated on the basis of *ease of use*. In this case, ease of use may become *the* critical indicator of quality to the user. Thus, usability is a necessary attribute for achieving quality in a product.

Usability through Iterative Design and Evaluation. In the initial design of a user interface, human factors specialists use their knowledge of human capabilities and the human factors literature. For example, one well-known principle from the cognitive psychology literature is that short-term memory is limited to about seven items, plus or minus two (Miller, 1956).[3] (Since Miller's work, there have been changes in theoretical models of memory; however, the fact of short-term or working memory constraints has not been contested.) This means, for example, that people cannot be expected to remember long lists of items in an auditory menu and, therefore, that auditory menus should be fairly short.

However, the psychological and human factors literature is rarely specific enough to describe precisely how a user interface should be designed. This is especially true when developing new technologies or designing complex user interfaces. Therefore, a human factors specialist designing a user interface relies on established knowledge and experience for the first "draft" design. This design is then tested for usability.

Usability refers to how easily the functions of a product or service are learned and used by actual users. For example, can users easily program a telephone for automatic dialing? Can users configure, schedule, and update call routing plans for their company's AT&T Advanced 800 service? Can users rapidly identify the cause of a problem on a company's voice and data networks through the graphical user interface of a network management system?

Usability is assessed through systematic usability testing. Many articles have been written on techniques for usability testing; articles by Whiteside et al.

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(1989) and by Gould and Lewis (1985) provide useful introductions.[4,5] In usability testing, two types of measures are often employed: behavioral and subjective. *Behavioral measures*, are obtained while a user is actually performing a task. Such measures include time to learn how to perform a task, speed of completing the task, number of errors made, number of times the user referred to a user's manual, and success in finding instructions in the manual. To obtain these data, a user or potential user actually performs the task, in the laboratory or in the field, using a prototype of the product or the product itself.

Subjective measures are also useful in usability testing and often include ratings on questionnaires or comments during an interview. Subjective measures provide information on a user's satisfaction with a product and a user's assessment of its value for helping accomplish a task. Both behavioral and subjective data provide information on the strengths of a product and on areas for improvement.

As a general rule, usability testing *early* in the design of a product is especially cost-effective because results can be used to refine product design before the product itself has been built. Because the product itself is not available early in the design process, prototypes of the product user interface are tested for usability. Prototypes may take different forms at different stages of the product realization process. At a very early stage, they may be simple paper-and-pencil drawings or screen designs rapidly created using a graphics editor. At later stages, they may be simulations of a portion of the user interface necessary for completing some particular task. Regardless of the particular form, prototypes can be used in the laboratory or in the customer's environment to obtain data on (1) the value of the design in facilitating the user's task and (2) the ease of use of the design.

In this issue, Benimoff et al. provide a more detailed account of the benefits of rapid prototyping, an overview of some graphics prototyping tools, and some examples of the use of rapid prototyping in product development.[6] Other authors also discuss rapid prototyping techniques.

Human Factors Throughout Product Realization

Human factors specialists play important roles throughout the product realization process. This section outlines the specific contributions that human factors specialists, as members of systems engineering and development teams, can make at each stage of the process. (Although the product realization process is described here as sequential, the stages often overlap considerably.)

Research, Standards, and Technology. Human factors work on any particular product or service builds on a foundation of *research, standards*, and *technology*. Relevant research includes research on human capabilities and on humans in interaction with technology. This research often uses sophisticated experimental designs and data analysis techniques. When the research is not tied to specific products but addresses general issues, the data may be useful for a variety of products and services. Israelski et al. provide examples of generic research on three different topics:

- Voice path cut-through time on a switch
- Distinctiveness and pleasantness of auditory alerting patterns
- Effectiveness of icons in human-computer interfaces.[7]

Standards for user-interface design are an integral part of the AT&T user-interface architecture. They provide guidelines for implementing interfaces so that there will be significant commonalities in both appearance and operational procedures. These commonalities make it easier for users to combine a number of AT&T products to meet their specific needs. Ideally, once a customer has learned how to use one product, the customer knows how to use others. Farber provides an overview of AT&T's user-interface architecture. This architecture provides a framework for defining commonalities in the components of user interfaces and for developing standards and software tools for the interfaces.[8]

Technology includes the hardware and software used both *in* the product and in *developing* the product. In the former case, it includes speech recognition devices and graphical user interfaces; in the latter, it

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includes programming languages, software tools and toolkits. and shell software architectures that make it both possible and easier to implement consistent user interfaces. Nakatani and Ruedisueli provide examples of technology used both in the product and in developing the product.[9] The authors describe a tool that provides assistance to users of emacs or vi who want to incorporate mm text-formatting commands in their files. (emacs and vi are text editors used in the UNIX® operating system; mm, for memorandum macros, is a general-purpose macro package used with the UNIX system nroff and troff text formatters.) The tool, a type of on-line help system, provides information about mm, including on-line documentation, sample documents, and plans for common documents. In addition, Nakatani and Ruedisueli describe TIPS, the framework used to develop the on-line help system. TIPS can also be used to develop help systems for other existing computer-based tasks.

Bennett et al. provide an overview of human factors research for new speech technologies, including text-to-speech synthesis and automatic speech recognition.[10] The authors cover a variety of research, much of it generalizable to many different products. In addition, they outline the role played by human factors specialists and linguists in developing the linguistic theory that supports creation of more natural-sounding synthetic speech.

Customer Needs and the Product Concept. At the initial stage of the product realization process, human factors specialists can profitably work in collaboration with market researchers and product planners to identify customer needs and define product concepts. Two contributions that human factors specialists can make at this stage are: (1) conducting *task analyses* and (2) creating and obtaining feedback on early prototypes of a product.

Task analyses of the processes customers use while performing their jobs identify critical tasks, bottlenecks in their current processes, and causes of error. These analyses thus identify critical areas for planning and designing new features. After task analyses have indicated where users need help in performing their jobs, preliminary prototypes of user interfaces of possible products can be taken to customers to obtain feedback—both on the features being considered for the product and on the manner in which the features are implemented in the user interface. Often a feature must be described concretely in the form of a specific user interface to get meaningful feedback from customers. This constitutes an early form of usability testing. Usability testing at this point is especially cost-effective because it provides feedback on the match of function and design to customer needs before product development begins.

Garberg et al. describe how task analysis was used to analyze the job of a telephone attendant in a small business.[11] This task analysis revealed that there are many "call passing" tasks handled by an attendant and that there are specific high-frequency tasks where productivity can be increased by a better-designed attendant console.

The Requirements Process. Human factors specialists are involved in the requirements process in several different ways. They are often responsible for systems engineering of the user interface, i.e., for writing the requirements for the user interface. These requirements specify to the developer how the user interface should look and function. As "user-interface systems engineers," human factors specialists work side-by-side with other systems engineers and developers to define the system and its user interface based on task analyses, user abilities and needs, and technological possibilities.

Work on the user-interface requirements should begin simultaneously with work on the functional requirements. In the past, work on the user interface was sometimes not begun until functional requirements had been defined; essentially, the user interface was treated as an "add-on" to the product. We are becoming more aware that user-interface design should be considered at the same time the functionality and the architecture of the system are being defined. Because the user interface is constrained by what is provided in

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the hardware and software, the requirements for a high-quality user interface must be considered while designing the architecture and specifying the product functionality. For example, how or whether applications interact in a complex software-based product can have major usability implications for users who need rapid access to multiple applications. Users may have to go through many more steps if applications cannot access each other. If user-interface design is delayed until architectural requirements have been completed, it might be too late to consider this effect on the user interface.

During the requirements process, prototypes of the user interface should be created and usability testing should be conducted on these prototypes. Such usability testing validates the initial design concepts and ensures that the user interface described in the requirements will be easy to learn and use.

The use of prototypes and usability testing before and during the requirements process is described in several of the following articles. Specifically, Garberg et al. describe an initial task analysis and then experiments that were conducted using two alternative prototypes of a new telephone number list-management capability for the 5ESS® switch. Benimoff et al. and Bennett et al. highlight the role that prototypes can play throughout the product realization process.

Development and System Test. As development proceeds, developers sometimes discover that cost and schedule do not permit implementation of the user interface as specified in the requirements. At this point, tough decisions must be made about what can be changed or even what must be omitted. Human factors specialists should be involved throughout the development process to provide input on user-interface priorities. Usability testing should be conducted on any major changes to the user interface to ensure that problems are not introduced at this point. In addition, system test provides a first opportunity for using the "real product" to determine whether it performs as specified in the requirements and whether it is easy to learn and use.

Pre-Introduction, Beta Test, and Beyond. Usability testing with customers is critical after a product has been developed but before it has been made widely available. During pre-introduction and beta test, we have our first opportunity to observe customers or potential customers using the "final" product to perform necessary tasks. Usability testing at this stage can be conducted either in the laboratory or in the customer's own environment. Data from usability testing at this stage can identify any unanticipated, serious problems that must be fixed immediately and can suggest enhancements for future releases of the product.

Kotsonis et al. describe several methods for obtaining customer input at this post-development stage.[12] *User perception testing* is a method for evaluating new products in the laboratory before the product is actually introduced. Kotsonis et al. cite examples of user perception testing for the successful HT 5300 cordless telephone. In addition, they describe evaluations conducted during product introductions and large-scale customer satisfaction surveys performed after customers have some experience with an AT&T product. Customer satisfaction surveys provide information about the perceived quality of AT&T products; such information can be fed back into the design of new generations of existing products or into the design of new products.

Delivery Support. Customer documentation for products includes user manuals, installation and maintenance guides, and training materials. This documentation (a) is a significant part of the user interface, (b) can often substantially affect a customer's ability to learn and use a product, and (c) almost always influences a customer's perception of quality. Work on these materials should begin relatively early in the product realization process. Ideally these materials should be tested for usability simultaneously with prototypes of the product.

Human factors specialists sometimes *create* customer documentation; more frequently, however, they conduct usability testing on the documentation and provide feedback to technical writers and course developers.

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The on-line help system described by Nakatani and Ruedisueli is an example of human factors involvement in the *creation* of user documentation. Kotsonis et al. provide examples of *evaluating* user manuals and installation manuals during user perception testing.

Summary

In this issue of the *AT&T Technical Journal*, the authors provide concrete examples of the methods and contributions of human factors specialists to the design of the human interface. Human factors work is described at numerous stages of the product realization process and for a variety of different products and services. Through these reviews, we illustrate the importance of human factors activities in ensuring usability and high quality—from the user's perspective.

AT&T has a long history of leadership in two arenas: (a) inventing new technologies and (b) providing products and services that meet our customers' needs. As our engineering skills and new technologies permit us to create more sophisticated and internally complex products, human factors specialists must ensure that the elegance and simplicity of the user interface is maintained.

Users perceive a product or service through the user interface; therefore, the user interface is a primary criterion for judging quality. That is, how easy it is to learn and use our technologically complex products determines, at least in part, how well they will be received. The user interface is the component through which users know the system; thus, it is the medium that reveals a product to be either a task facilitator or a task in and of itself.

By starting from a knowledge of human abilities and by conducting iterative usability testing, human factors specialists play an essential role in ensuring that AT&T's products make users' tasks easier.

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