HUMAN FACTORS IN THE DESIGN OF TELEPHONE FEATURES

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Technology is providing users expanded control over telecommunication services. However, this control increasingly depends upon successful structuring of the human/machine dialogue. In this paper, we describe several phases of dialogue design, including task analysis, generation of alternative designs, and evaluation of design proposals. Examples of these phases are drawn from small business systems as well as systems designed for wide residential deployment. We give special emphasis to the evaluation phase, showing how human factors methods are employed to ensure a dialogue design supporting both novice and experienced users of services.

Introduction

Consider this scenario illustrating uses of the telephone. An engineer from Chicago is preparing to leave for a conference in Denver. Before leaving, she programs her phone system to recognize two very important numbers. Later, at the Denver conference, a phone in the conference room rings when a call from one of these numbers is forwarded from the Chicago office to the Denver number. Meanwhile, less urgent calls to the engineer's office are being forwarded to a secretary in Chicago, thereby avoiding long-distance charges for these calls. Returning to her office in Chicago, the engineer reprograms her phone so that very important calls cause her phone to ring in a distinctive way.

In this scenario, the engineer exercises a degree of control over the operation of a telephone that was impossible only a few years ago. The control is possible both because of technological developments in hardware and software and because the service, through its user interface, supports a productive dialogue with the user. This human/machine dialogue lets the user take full advantage of the power of the communications system. Optimizing such dialogues is a great challenge facing human factors engineers today.

To better understand this challenge, consider Figure 1, which illustrates elements of the human/machine dialogue for a telephone

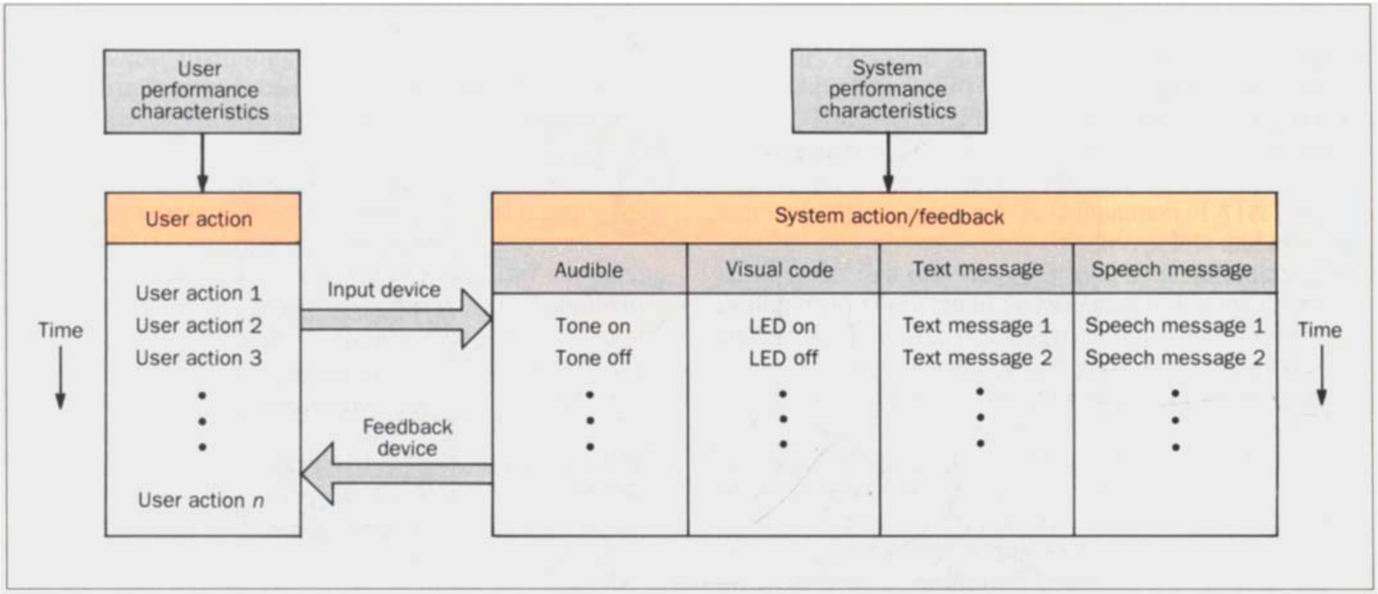


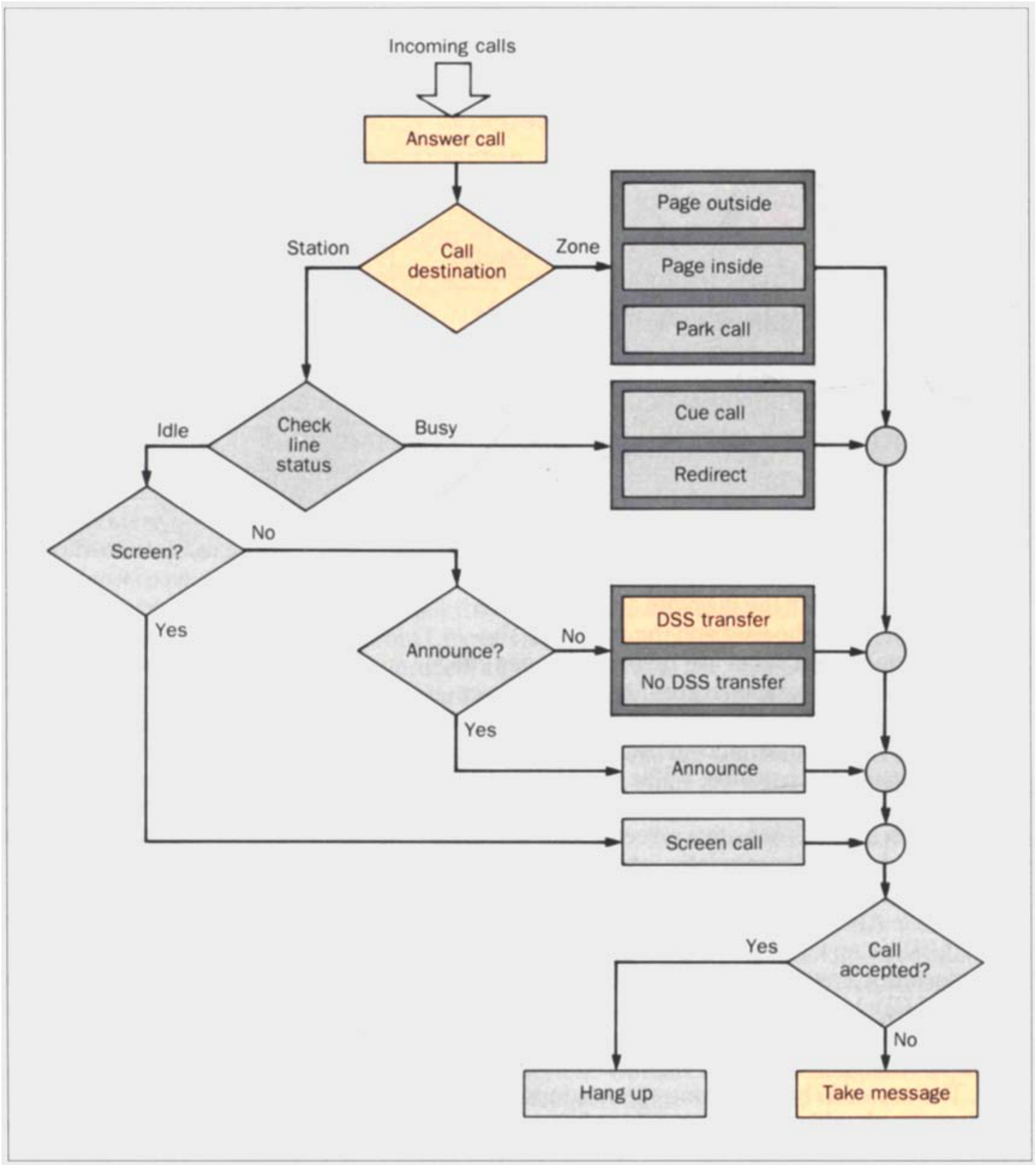
Figure 1. Components of feature operation specifications.

feature. At the heart of the dialogue are information exchanges between the user and the machine. The feature designer must sequence these exchanges effectively, maintaining operational consistency whenever appropriate. In addition, the designer must understand the capabilities and constraints of user input devices and system feedback mechanisms. While most telephone features rely on button and switchhook input, new input devices, such as touch-sensitive screens, magnetic card scanners, and speech recognizers, are becoming increasingly feasible. Likewise, while most existing telephone features take advantage of audible tone and light-emitting diode (LED) lamp feedback, increasing numbers of telephone features provide feedback through liquid-crystal displays (LCDs) or through synthesized speech.

The user brings to the human/machine dialogue special information processing capabilities and limitations. The user also brings strong expectations about how features should work. The machine brings to the dialogue particular input and output devices, as well as inherent product "architectures" that constrain the design of new features and present important feature interactions between new and existing features. The designer of telephony features must ensure a match between the resources of the user and those of the machine.

This paper describes several phases in the design of the human/machine dialogue for telephone features. In each phase, human factors research yields prescriptions for the design of telephony features. In the first phase, the prescription is based on detailed task analyses of users' communication requirements. In the next two phases, prescriptions are made for reducing unnecessary cognitive complexity in the operation of communication tools. The research presented here focuses on the development of specific products, but results of the research have influenced the development of other services that attempt to provide users with extensive control of communications equipment.

Figure 2. Partial task analysis for a small-business attendant. DSS represents direct station selection.



Early Stages of User-Interface Design

Before planning the user interface for a proposed feature, the designer must analyze in detail the task or series of tasks that a user is trying to perform. Human factors engineers use a variety of formal research methods, such as task analysis and process flow charting, to discover and describe these user tasks. Once they understand the tasks and subtasks reasonably well, human factors engineers identify areas of user confusion or frequent error. These areas become critical points in the design of a new feature or service.

Human factors engineers at AT&T use task analysis extensively as a preliminary step in designing new telephone features. A recent example is the development of the Merlin® communications system. In this project, human factors engineers interviewed employees in over 100 small businesses ranging from legal and medical offices to wholesale distributors and flower shops. These structured interviews yielded information about small business customers, their patterns of telephone usage, and their particular telecommunication problems.

Such customer studies, combined with earlier field research for AT&T products such as the Horizon® communications system, showed that a critical job lies with the telephone attendant in a small business. In many respects, the job is unchanged from the local "switchboard" operator of the past. A basic attendant function is to answer incoming calls and then to screen and pass these calls to employees within the business. If the call cannot be passed because the called employee is busy or does not answer, the attendant usually must take a message.

The task analysis showed that an attendant handles a high volume of calls on many lines, and often spends considerable time servicing individual calls. In addition, an attendant is responsible for other job assignments and is away from the telephone for significant periods of time (e.g., during the lunch hour). Therefore, two design goals were (1) to make it easy to integrate backup coverage with primary attendant coverage and (2) to maintain consistency of feature operation across the system. By satisfying the second goal, the feature designers expected to keep training time short and to improve performance of occasional substitute users.

The attendant job appears simple, yet analysis showed many call passing variations. Figure 2, which was adapted from a partial task analysis completed by human factors engineer J. P. Duncanson of AT&T Bell Laboratories, shows several decision points and at least 10 subtasks that may be performed by an attendant. For example, an attendant at an auto dealership would first answer a call with a personalized greeting. If the call is for someone in the service and parts department, the attendant would follow the subtask procedure of paging an employee in that department. On the other hand, if the call is for the business owner, and the owner is not available or not taking calls, the attendant would have to decide where to direct the call. The attendant might first determine if the store manager is available by looking at the station status field on the attendant console to see whether the manager's line is idle. If so, the attendant must decide whether to screen or announce the call and then follow one of several call passing procedures. If the call is not successfully passed (e.g., if the store manager chooses not to answer), it returns to the attendant, who can try to pass the call to someone else or take a message.

These call passing routines may vary according to the type of business and the destination of the call. For example, retail establishments are more likely to use call paging or call parking procedures to pass calls, since their employees move around frequently within the store, while professional offices are more likely to screen or announce calls routinely. Personal lines may be answered with a person's name, while an incoming wide-area telephone service (WATS) line may be answered with a company or department name. And, finally, the boss' line may be answered and passed in a special manner.

Once call activities and tasks have been analyzed, human factors engineers begin to look for ways to simplify and enhance features and to solve user problems. In Figure 2, highlighted subprocesses and decision boxes show areas where bottlenecks and errors have been reported from the field. While designing the user interface of a new attendant console and attendant features, human factors engineers in AT&T's Small Business Systems Laboratory concentrated on improving the operation of these high-frequency tasks. They made physical design changes in the attendant console, enlarging and repositioning high-usage function buttons (*Hold* and *Disconnect*). These changes were intended to help attendants cope with a high volume of calls—to terminate, accept, and hold calls easily.

In addition, the station information field was increased to contain information for 40 stations, and the number of station "pages" needed to represent the entire system was reduced from three to two. These additional changes were intended to provide easier access to information about individual station status and to station buttons used in the direct station selection transfer procedure. Call information was also enhanced on the LCD to include return-from-transfer information, which is used to manage unanswered calls more expeditiously.

During the evaluation of the Merlin II communications system, human factors engineer Richard L. Pastore videotaped and surveyed attendant operators to assess their satisfaction with the operation of the new attendant console and attendant features. The attendant operators' responses confirmed that the physical and operational changes simplified call handling operations at the attendant position. Moreover, ratings of overall satisfaction and ease of use from both new and former users were unanimously favorable.

Engineering the User Interface

In some projects, extensive experimentation must follow the early stages of user interface design. Recent development of the telephone-number-list manager for use on the 5ESS® switch illustrates methods employed in such projects. The crucial design problem for the list manager was to reduce the complexity of an existing user interface that required many steps and acts of memory retrieval while providing only limited feedback to users.

Customers can subscribe to one or more features that require phone-number-list management. In each of these features, the number of any calling party is compared with numbers on the list. If there is a match, then the call receives special treatment. For example, the selective distinctive alerting feature provides a distinctive ringing to the subscriber's phone when there is a match between calling number and a listed number. Another feature, selective call rejection, routes matched callers to a recorded announcement telling them that the called party is refusing their calls. Other features requiring the list manager are selective call acceptance and selective call forwarding (which was used in the scenario at the beginning of this paper).

The list manager offers users six basic operations:

1. Add phone numbers to the list
2. Remove single numbers from the list
3. Remove all numbers from the list
4. Request that the numbers on the list be read
5. Turn a feature on or off
6. Request instructions.

In an early version of the manager, the user dialed one of two access codes to begin a list-management session. This version of list management, which runs on the 1A ESS™ switch, is represented schematically in Figure 3. The figure shows the basic structure of the interface. When users dial an access code, they are given access to a subset of the list-management options. Users also dial access codes to activate or deactivate list-management features.

The list-management sessions are highly interactive: users are prompted continually for input and are given feedback regarding successful and unsuccessful actions. For users with analog phones, prompts and feedback are provided entirely through auditory announcements. These announcements are critical; they provide both instruction for novice users of the feature and the feedback and prompting needed by all users. Users

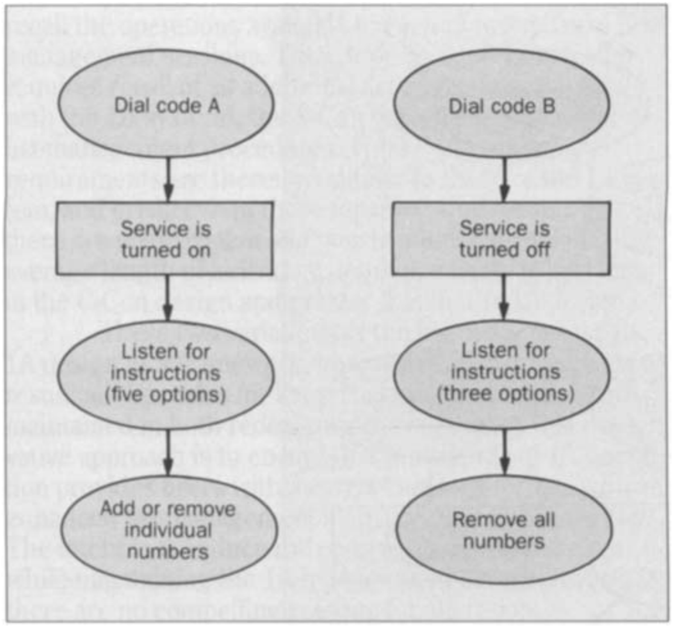


Figure 3. Schematic illustration of the 1A ESS switch list-management user-interface operation.

having a digital phone set with feature buttons and a display, such as the engineer in the initial scenario, may receive additional prompts and feedback through button lights and display messages.

Research conducted at AT&T Bell Laboratories has explored the design of similar programming procedures with which users can customize their telephone systems. For example, Petrick reported success in designing a programming procedure for a small communications system.[1] This system required the user to consult written instructions and used only audible tones and LEDs for prompting and feedback, yet it proved effective in laboratory and field trials. However, Petrick found that additional sources of feedback (LCDs) were required for programming larger and more complex systems.

With its extensive system of announcement prompts and instructions, the 1A version of list management provides an environment in which written instructions are largely superfluous. Yet there was concern that some operations were causing users difficulty. For example, feature activation and deactivation are side effects of initiating different types of sessions; there are no instructions about directly activating or deactivating features (see Figure 3). Moreover, instructions are distributed between different branches of the menu structure. To move from one branch to the other, the user ends one session and starts another with no instructions or prompting between. Before undertaking costly development of the list-management services for the 5ESS switch, we needed to know how seriously these complexities compromised user performance and satisfaction with the services.

One approach to reducing complexity is to consolidate the instructions in a single branch of the interface. At the same time, the resulting increase in length of instructions could overburden the attentional resources of users, leading to increased error rates and dissatisfaction with features.

Thus, if instructions and prompting are consolidated in the list-management interface, there is a potential for realizing both benefits and losses. Two new designs of the list-management interface were therefore proposed. These designs added new announcements and consolidated the 1A system announcements. The new designs differ in the extent to which they place demands on either human recall or human instructional processing and decision making.

In one design, users are given consolidated instructions covering every aspect of list management operation (except instructions about dialing the code to access the list-management session). This design is termed the *completely consolidated* (C-Con) design, since it provides all instructions under one branch of the interface (i.e., in one menu). Figure 4a shows that this arrangement reduces memory demands on users: it requires that they recall only a single access code. Moreover, unlike the

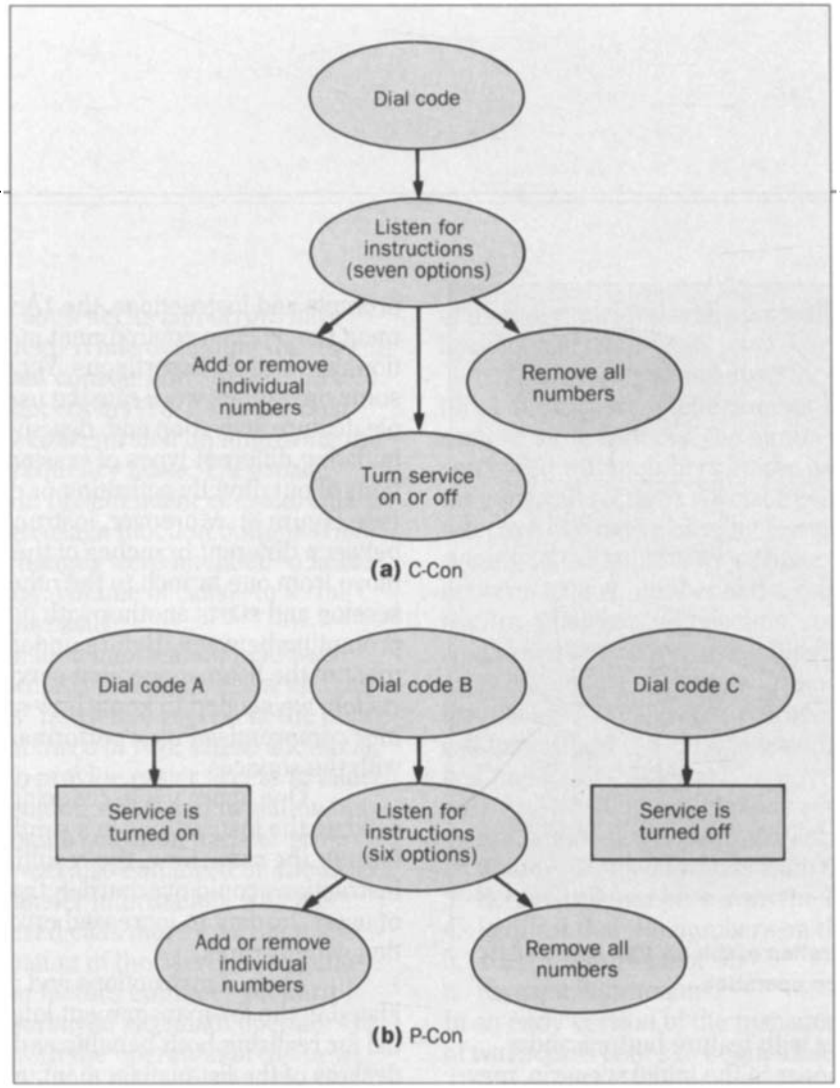


Figure 4. Redesigned list-management interfaces with (a) expanded and consolidated announcements and one access code to be recalled and (b) partially consolidated announcements and three access codes to be recalled.

users of the 1A design, users here need not recall the association between subsets of list-management operations and access codes. The cost of these memory reductions is a potentially longer auditory search through the consolidated instructions to find the appropriate option.

However, if users can interrupt announcements freely after gleaning the information they need, the longer consolidated announcement menus can be used without marked increases in auditory search time. Many AT&T products [e.g., the AUDIX (audio information exchange) voice-mail system] allow users to interrupt audio announcements, so that experienced users of a service may complete tasks more quickly. All three designs evaluated in the studies reported here allowed the user to interrupt announcements. For the C-Con design, we suspected that the ability to interrupt announcements would provide users with the advantages of consolidated announcements, without imposing on them the full costs of longer auditory search.

In the second design, termed the *partially consolidated* (P-Con) design, all announcements are again consolidated in one branch of the interface. However, feature activation and deactivation instructions are omitted. Figure 4b shows that the P-Con user must remember three access codes. Relative to the 1A design, the P-Con and C-Con designs share this advantage: users need not recall the operations available in each of two types of list-management sessions. Thus, though the P-Con design requires recall of an additional access code (compared with the 1A system), the P-Con design eases recall of list-management procedures. Total P-Con memory requirements are therefore similar to those of the 1A system, and greater than those for the C-Con design. Since there are no activation and deactivation instructions, the average length of individual announcements is less than in the C-Con design and greater than in the 1A design.

These two variations of the list manager use the 1A design as a framework, borrowing from it freely. As a result, all the codes for list-management operations are maintained in both redesigns. The reason for this conservative approach is to ensure that knowledge of 1A operation provides users with a correct analogy for use with an enhanced list-management interface to the 5ESS switch. The intent is to reduce the complexity of the interface while maintaining the 1A type of operation wherever there are no compelling reasons for alteration.

Chechile et al. report data suggesting that complexity is proportional to the number of procedural steps that a user must recall.[2] This view implies that the 1A design is the most complex of the three designs, followed by the P-Con design. Nonetheless, the longer individual announcements found in the C-Con design may require users to engage in more verbal information processing when completing a typical task. Likewise, the larger number of options simultaneously available under the C-Con design may require users to expend more effort to choose appropriate actions. These empirical uncertainties, among others, motivated the next phase of user interface design—evaluation.

The Evaluation Phase

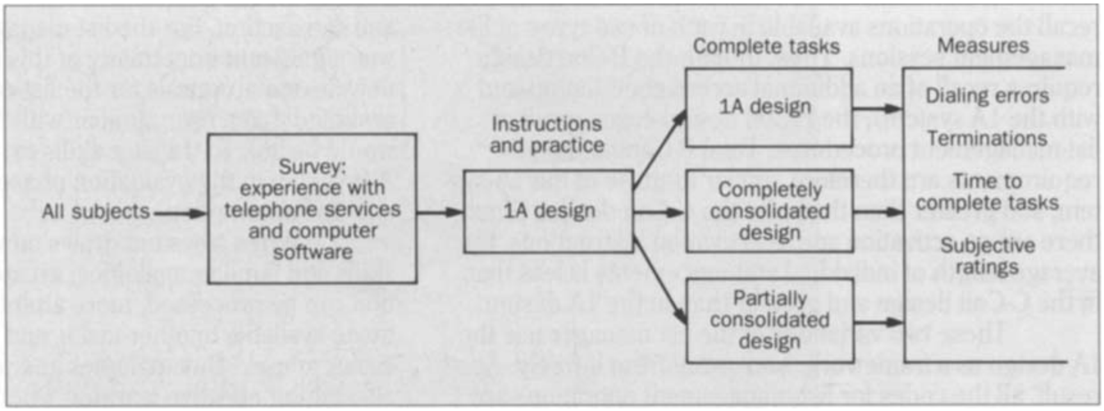
After completion of task analyses and generation of design alternatives, important areas of uncertainty frequently remain about user reaction to alternative design characteristics. In such cases, experimental methodologies can provide valuable estimates of user performance and satisfaction. For the list-management designs, there was significant uncertainty of this type. Furthermore, the new design proposals for the list-management capability assumed that a user familiar with 1A list management would be able to transfer skills to a redesigned interface. A first step in the evaluation phase of this project was to test this assumption.

When a system draws on well-practiced, routine skills and familiar analogies, greater amounts of information can be processed, more attentional resources can be made available to other tasks, and the system seems easier to use.[3] But analogies and practiced skills may also inhibit effective learning when used in the wrong context. In such cases, the user imposes a simplifying—albeit erroneous—model on the system, and thereby complicates initial interactions with it.

Such an effect characterizes what Carroll and Rosson call the "assimilation paradox."[4] The paradox is that novice users of computer equipment may fail to interact with a computer successfully either because they have no applicable analogies with similar interactions, or because they have and use analogies, but the wrong ones. Bloom reports findings that support such an effect when he tested the comprehensibility of terms used to describe operations in a text editor.[5] Using one common method for generating terms, Bloom observed errors suggesting that users were unable to interpret terms with respect to a familiar analogy. Using another common method, he found "assimilation" errors (i.e., errors suggesting that users employed inappropriate analogies to interpret terms).

The evaluation phase began with an experiment to determine the extent to which the C-Con and P-Con designs succeeded in minimizing problems due to the assimilation paradox while maximizing useful analogies between 1A and the redesigned interfaces. The evaluation was based on the hypothesis that little or no adverse effect on performance and rated ease of use would be observed for the redesigned interface among those users who were familiar with the 1A interface.

Figure 5. Design of the transfer study (Experiment 1).



Experiment 1: Transferring Skills. Each of the three interfaces was simulated on an AT&T 6300 personal computer equipped with a Natural Microsystems' Watson telephone management card. The simulations created a true-to-life imitation of the service that users would experience on the network. The computer received and interpreted button presses from a standard telephone set and played announcements over the same telephone. In addition, the computer recorded each event in the interaction between subjects and the simulation. Thus, as each subject completed the set of assigned tasks, the computer recorded all errors, all announcements played, and all user actions. Each record contained the time of the event, measured to the nearest tenth of a second. The computer informed subjects whether a task had been finished correctly after each task completion.

Volunteer subjects were given written and oral instruction in using selective distinctive alerting, a feature requiring list management. The instructions explained the use of the 1A interface for list management. Subjects first practiced on the 1A user interface. The set of practice tasks was designed to quickly acquaint users with the complete range of list-management capabilities. Next, they completed two sets of experimental tasks using either the 1A or a redesigned interface. The design of this study is shown in Figure 5.

The design of this study gave volunteers doing tasks on the 1A interface a substantial advantage over the other two groups: this group had practiced with the interface before starting the experimental tasks. For the other groups, this same practice with the 1A interface was potentially confusing.

Results of multivariate analysis of variance (MANOVA) of performance variables are shown in Figure 6. The C-Con group was reliably faster at completing tasks than the 1A group. The difference was small, and the average difference observed per task (14 seconds in favor of the C-Con compared with the 1A group) was attributable to the extra steps required by the 1A operation. There was no speed advantage for the C-Con compared with the P-Con design.

A "task error" was recorded whenever the user's list failed to match the goal list for the task. In this experiment, the three designs had similar rates of task errors.

An "interaction error" was recorded each time a user action caused an error message to be played during a session. Ordinarily, announcements following error messages told users to continue with the session. But for subjects who made three consecutive interaction errors, the feature would ask them to hang up and a "termination error" was recorded.

Their marginally lower rates of interaction and

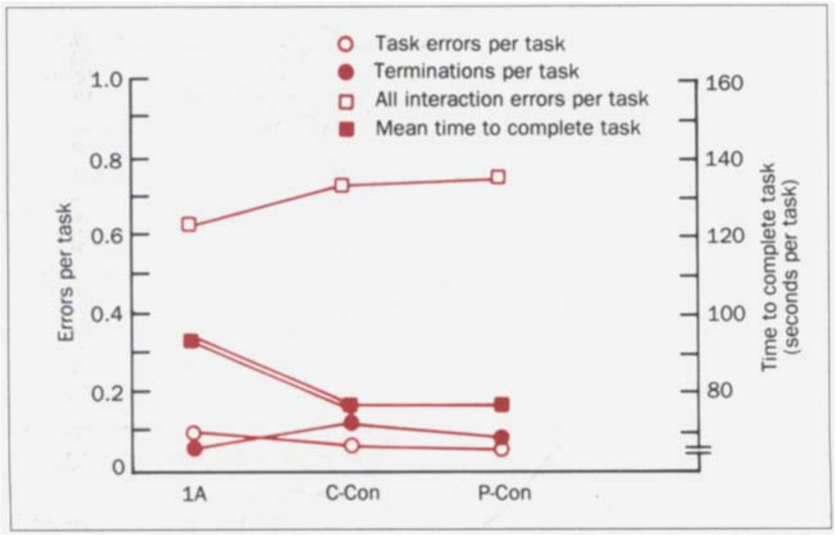


Figure 6. Performance data from Experiment 1. Double lines connect statistically reliable comparisons (confidence in the sign of the difference exceeds 90 percent).

termination errors show that the well-practiced 1A users were less error-prone within list-management sessions. However, subjects using redesigned interfaces were able to overcome these errors, so that they were just as likely to complete tasks correctly, and they did so with a speed advantage. Moreover, their ease-of-use ratings were as favorable as those of the 1A group. Thus, in spite of changing from 1A to a new interface, C-Con and P-Con users were still able to perform at levels comparable to the more practiced 1A users. Significantly, when users of the C-Con interface were asked to compare it to the 1A interface used initially, every one of them preferred the C-Con design. P-Con users also voted for the P-Con design in preference to the 1A, though this vote was not unanimous.

This experiment showed no evidence of the assimilation paradox among users of the redesigned interfaces. Prior practice with the 1A interface produced slightly fewer interaction/termination errors with that interface than with the C-Con design. Yet tasks were completed more rapidly with the C-Con design. Ratings and user preferences suggest similar or greater user satisfaction with the C-Con interface, leading to faster but slightly more error-prone performance compared with the 1A interface. (Experiment 2 shows a smaller accuracy advantage for the 1A when subjects are unfamiliar with any list-management interface.) The experiment also suggested that persons familiar with the 1A interface show a moderate degree of skill transfer.

Experiment 2: Novice Users. The three interfaces were compared for users who were unfamiliar with any version of the list-management capability, including the 1A version. This experiment evaluated whether applying the complexity literature (e.g., Reference 2) to the design of the C-Con interface had led to an operation that was simpler. There was one principal concern with the C-Con design: because it offered longer announcements with more simultaneously available options than the other two designs, C-Con users might need to expend more effort to process information about the options. This greater effort could adversely affect performance and satisfaction. If they were typically unwilling to interrupt the longer announcements, novice users with no prior experience of the 1A design might find the C-Con

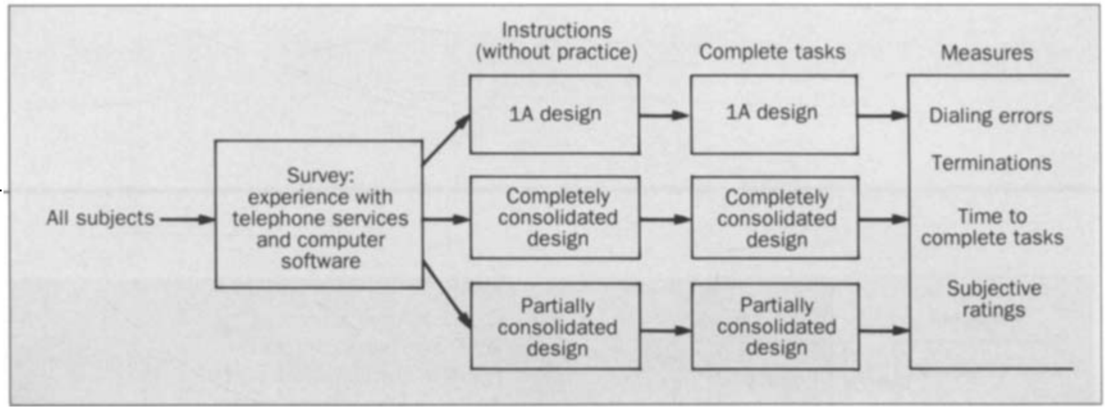


Figure 7. Design of the complexity comparison study (Experiment 2).

design unsatisfactory, for example.

The design of Experiment 2 is shown in Figure 7. The experiment used the same simulations, surveys, and tasks given to volunteers in Experiment 1. In Experiment 2, three groups of volunteers were given instructions on the use of either the 1A interface, the C-Con interface, or the P-Con interface. In contrast to Experiment 1, subjects were given no prior practice with a list-management interface before starting the experimental tasks. This meant that subjects were less familiar with the operations of list management; it also meant that no group had the advantage of prior practice, unlike the 1A group in Experiment 1. The computer randomly ordered and presented 17 list-management tasks from one of the two task sets used in Experiment 1. Subjects completed the tasks using the interface on which they had received instruction.

MANOVA was again performed on the performance data. The rate at which subjects completed tasks incorrectly is plotted as open circles in Figure 8. Task errors were least frequent in the C-Con group, though the differences were statistically negligible. The average time to complete tasks showed much more pronounced differences. The C-Con group was, on average, 52 seconds per task faster than the 1A group. Bayesian statistical analysis showed that this difference in favor of the C-Con group was highly reliable, and that the "true difference" was between 27 and 77 seconds. (The value of the difference is 90 percent likely to fall within this interval.)

The C-Con group was also reliably faster than the P-Con group, and analyses indicated a high degree of certainty that the C-Con interface leads to faster performance than both the 1A and the P-Con interfaces (Bayesian confidence exceeds 99 percent that C-Con performance is faster). No reliable effects of interface type were found for either termination or interaction errors.

This experiment suggests that the list-management interface poses difficulties for the novice user. The C-Con interface reduced the number of acts of recall that were required to complete tasks, yet subjects using this arrangement were just as likely to commit termination, interaction, and task errors. Close inspection of errors revealed that subjects were prone to attempt invalid sequences of operations no matter what interface was employed. For example, when trying to add a number to their list, they would often start to dial the number directly. But any of the arrangements required that users first enter an operation code, indicating whether they intended to add or remove an entry from the list, and only then enter the number to be added or removed.

Still, the C-Con interface enabled one substantial performance improvement—speed. This was not entirely surprising since the C-Con design reduced the number of acts of recall by reducing the number of steps needed to complete list-management tasks. But unlike the results in Experiment 1, the size of the speed advantage appears greater than any effect attributable to the savings of a few steps per task.

Other data provide insight into the causes of the speed advantage. First, in every interface condition, subjects were prone to interrupt instructional announcements. Recall that the C-Con interface traded an increase in the length of announcements for a reduction in the number of procedural steps. The data suggest that the increase in announcement length resulted in a less-than-proportional increase in information processing requirements. When they had heard the instructions they needed, subjects proceeded without listening to material irrelevant to their current task. Under these circumstances, the C-Con interface benefited from reduced

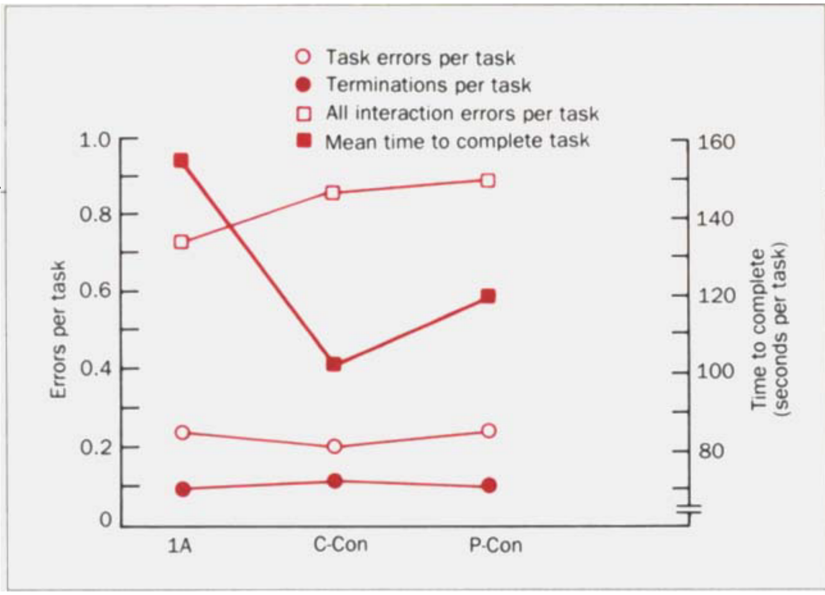


Figure 8. Performance data from Experiment 2. Bold lines connect statistically reliable comparisons (confidence in the sign of the difference exceeds 95 percent).

memorization and fewer steps, without incurring the full cost of additional announcements and choices.

The second clue concerning the faster performance found in the C-Con interface comes from the post-experiment ratings. When considering the interface that they had used in the experiment, subjects using the C-Con interface gave it reliably higher ratings for overall ease of use. Subjects also rated component operations such as adding or deleting numbers, removing all numbers, having the list read, and turning the service on or off. The average across these ease-of-use measures showed reliably higher ratings for the C-Con interface. Apparently, subjects felt that the C-Con interface was easier to use even though they made mistakes at the same rate as the 1A group.

We believe that the C-Con advantages are due to reduced complexity of the design. Conceivably, characteristics of the design other than reduced complexity could account for these results. For example, C-Con users might feel compelled to do tasks quickly in order to adapt to the pacing and positioning of instructions. Yet subjects did not report feeling rushed by the interaction, nor did the rating data show any dissatisfaction with C-Con interaction that might be expected from rushed users.

These effects strongly suggest that the C-Con interface enables performance improvements and greater satisfaction among first-time users of the list manager. These experiments and additional discussions with customers have led to the standardization of a C-Con interface for all features using the list manager on the telephone network.

Many other design requirements resulted from experimentation with the list-management interface. For example, results from these experiments have been employed for designing other 5ESS switch features, such as enhanced list management for the speed calling feature. Many of the results are applicable to a growing set of new telephony services. For example, we found that error announcements must not be interruptible, though user prompts should be. User errors frequently occurred in patterns that resulted in three or more consecutive errors. If associated error messages were interruptible, then these patterns could cause the list manager to end a session without ever giving the user an indication of error. Other requirements resulting from the study include specification of maximum and minimum expected holding time for list-management sessions. These data are needed for provisioning the switch with list-administration hardware.

Conclusion

Several forces are currently at work to increase user control over telecommunication services. Among these are the expansion of new services and the increasingly powerful languages for supporting the interaction between system and user. For example, graphic prompting and feedback on video terminals will soon be available for the telephone programming environment, so that user/system interactions such as those described in Figure 1 will grow in complexity and potential controllability by the user.

The realization of this technological potential in the form of flexible communication tools will depend increasingly on human factors methodology such as task analysis and complexity evaluation. As the variety of communication tools expands, users will increasingly expect that telephony services reflect a detailed understanding of their communication tasks and provide the simplest procedures for completing these tasks. Technically excellent products, based on well-crafted human factors research, can satisfy these expectations and define new standards of voice communication.

The most important evaluation of feature operation is made by customers who own and use our products. New features are routinely tested at trial sites in central offices and businesses. As part of the field evaluation team, the human factors engineer gathers data for evaluating new product performance—data that often result in minor design changes before large-scale product deployment or manufacture. Customer survey data collected during field trials also provide insights into customer call activities and tasks. In these ways, the feature design process comes full circle as the completion of one feature operation design provides the "task analysis" foundation for designing the next feature or service.

Acknowledgment

The experiments in the list-management interface were made possible by the simulations programmed by James Bond-Harris. We gratefully acknowledge his help.

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Biographies (continued)

factors and user-interface design for the 5ESS® switch. He received a B.S. in psychology from the University of Illinois and a Ph.D. in cognitive psychology from Rice University. He joined AT&T in 1974. Mr. Millen's group works on simulation and evaluation of new user interfaces for small business products and services and user-interface design for the Merlin® communications system products. He received a B.A in English and linguistics from Columbia University and a Ph. D. in Cognitive Psychology from Rutgers University. He joined AT&T in 1978.

(Manuscript received June 21, 1989)