VOICE MAIL

Voice mail is a general term that can be applied to a variety of computerized tools to record and play back telephone messages. Although mechanical telephone answering machines have existed for several decades, computer-based message systems provide new opportunities for communication. In this article, we will refer to voice mail as both an information technology (IT) and a form of computer-mediated communication (CMC). The specific computer architecture and file access requirements of voice mail are not the focus of this article. Instead, we will emphasize user-centered design issues and other "nontechnology" factors that most affect the successful use of voice mail by individuals and organizations.

Specific topics in this article include voice mail usability and task utility features, and user characteristics and organizational factors which affect the success of voice mail technology implementations. Examples are drawn from the authors' study of voice mail system development and integration in state government offices. This article also addresses concerns associated with degraded system performance and possible difficulties which arise when designers' and users' expectations for voice mail functionality are not matched.

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Voice mail, like e-mail and electronic facsimile (fax) machines, has become a widely accepted and used CMC tool in many organizations for rapid information exchange. These CMC systems are successful because they combine traditional types of communication (oral conversations, letters, and memos) with faster and more flexible message delivery capabilities. Voice mail is especially valuable as a tool that can support the variety and variability of spoken language without the sender and receiver of the message being available at the same time. Voice mail has a fundamentally different role than CMC systems designed to support group conferencing and real-time collaboration between people who cannot be in the same place at the same time. Any form of mail exchange, whether it is based on physical material or electronic information, emphasizes sequential, asynchronous elements of messages sent from one person to another.

Voice mail is similar to, but not identical with, automated voice response (AVR) systems. In fact, many voice mail users will set up their system user area ("mailbox") using an AVR technology. The basic role of an AVR system is to guide a user (who is using a telephone as the system interface) through a variety of options and commands using the limitations of a 12-key tone telephone interface. The AVR system uses computer pattern-matching capabilities to recognize differences in tones generated by the individual keys or differences in the spoken sounds of the numbers. These pattern-matching capabilities allow the user to select from a variety of menu options stored electronically in the computer system. The user is then able to configure mailbox features, in an interactive real-time fashion according to changing situations, task needs, or user preferences, without requiring extensive memorization of commands and options.

The discussion of voice mail, on the other hand, places an emphasis on the capabilities of exchanging voice messages when any or all of those sending or receiving the message are not able to have a regular spoken telephone conversation. Many basic voice mail functions, in fact, do not require any AVR interactions or computer-based IT capabilities. Even though most voice mail systems provide some AVR capabilities ("Press 0 to reach the operator immediately"), the basic message exchange functions of voice mail do not require any specific telephone hardware for the person sending the message to the voice mail user. More elements of AVR will be discussed in the section entitled "Basic Voice Mail Interface Tasks."

ADVANTAGES OF USING VOICE MAIL

A 1978 study showed that three out of four telephone calls were incomplete on the first attempt and 50% of the telephone calls completed require only one-way transmission of information (1). These statistics demonstrate that repeated and failed attempts to contact another person via telephone ("telephone tag") can be a waste of time and system capacity, as well as frustrating to the communicators. A system such as voice mail allows the sender to communicate with the intended person in his/her own voice and accomplish one-way transmittal of information without interrupting the intended recipient. In addition, voice mail does not require that the receiver of the message be available to answer the telephone when the sender calls. Therefore, voice mail can be an effective form of communication even beyond regular business hours, or when the voice mail user is far away from his or her regular work location.

Voice mail can be considered to be a form of answering machine with several enhanced capabilities. It offers greater control over remote retrieval of messages. In addition, voice mail offers an increased variety of sending and receiving options, which are not feasible using traditional telephone links. For instance, with a voice mail system, a sender can deliver an identical message simultaneously to a group of people or forward a received message to another mailbox with the sender's additional comments. Voice mail also allows the user to play back messages at variable speeds, quickly rewind or fast forward through messages, or pause messages to accomplish other tasks. The voice mail computer also serves to automatically record time and date information of received messages, include the name and mailbox of the person calling if that person is connected to the same system, and provide alerts to the user when new messages have arrived.

The host voice mail computer is operated remotely and may interact with Centrex extenison, Caller ID functions, and other computer data codes exchanged between rings when a call is placed. The voice mail system is integrated with other elements of the electronic telecommunications infrastructure. Therefore, the user has access to voice mail functions without a physical answering machine attached to the user's telephone. This feature has a significant advantage in terms of ensuring system compatibility and uniformity for large organizations, with a minimum of hardware to maintain. A major disadvantage to a centralized voice mail host computer is that heavy system use or computer breakdowns cascade throughout the organization very quickly and affect most or all system users simultaneously. The impacts of these trade-offs are discussed later.

BASIC VOICE MAIL INTERFACE TASKS

Voice mail systems use the standard 12 keys on a tone telephone (0–9, *, #) as the interface to access all system functions. This interface allows the user to enter commands that will activate various functions within the system without requiring advanced voice recognition tasks or complex alphabetic characters. To date, such features have been beyond the technical feasibility of any information technology in widespread commercial use. There are two primary requirements to the voice mail interface. It must support the very limited range of possible characters ($\log_2 12 = 3.585$ bits). Also, it must be compatible with human users' limited capability for processing auditory information. Unlike computer screens, the voice mail interface requires a very sequential style of interaction and is limited by the user's ability to remember long sequences of options when presented aurally. (This limitation operates both in terms of the number of options presented at one time and the length of time between the beginning and end of the voice prompt for novice users who are not familiar with system options.) These constraints require the voice mail interface to provide a limited number of menu options at one time, often no more than four or five.

Each user on the system has a personal mailbox number and a security password. The users can access their mailboxes from any tone telephone. In order to ensure privacy and con-

fidentiality in accessing voice mail, users must use the security password to retrieve and review messages. Prerecorded commands or prompts guide users through the process of dealing with the messages in their mailboxes. Both the caller and recipient interact with the voice mail system using an automated voice response interface strategy. The AVR allows users who are not familiar with all system commands to be guided through the voice mail menu options. Experienced users may be able to skip most AVR prompts (except for the initial voice mail announcement that greets the caller) by directly entering commands. Most modern AVR interfaces allow two methods of increasing speed and satisfaction with the system for experienced users. One method is "type-through," where any relevant command can be entered during the prompt for any of the potential menu options. The second is "type-ahead," where the user can at once type a series of commands that correspond to multiple levels of menu navigation.

Answering an Incoming Call

The voice mail host computer answers an incoming call after a predetermined number of rings, based on whether the recipient does not answer the phone or is already involved in another telephone call. When there is no answer, the computer answers after approximately four rings. If the recipient is already using the telephone for another call, the computer intercepts the call and answers after one or two rings (instead of the busy signal). After playing a recorded greeting, the voice mail computer records the caller's message and attaches the time, date, and length of call information. If the caller's telephone is part of the same voice mail system, the computer also attaches the sending telephone number (mailbox) information. In many systems, the caller is also given the option of pressing an escape key (usually "0") to transfer to a secondary telephone number designated by the recipient. This option is provided for callers who prefer not to leave a recorded message or who may need to speak with a human intermediary immediately rather than wait for the recipient to retrieve the message.

The voice mail system AVR then directs the caller to record a message in his or her own voice. This message is stored in the recipient's "mailbox," which is an electronic storage area in the voice mail host computer where messages are held for review and processing.

Retrieving a Message

When the voice mail computer completes the message-recording process, it sends an electronic alert signal to the recipient's telephone. The recipient has the option of an auditory (stutter dial tone) or visual (flashing light, included in many modern telephones or user-installable alert devices) alert to the presence of messages in the mailbox. In order to check messages, change options, or send a message, the recipient/user dials an access telephone number, which is answered by the voice mail computer's AVR system. (A user who calls from a telephone other than his or her own telephone number, has the option of entering his or her own mailbox number, which corresponds to the telephone number.) The user then enters a password and is presented with a menu and message stating the number of new and previously saved messages. The AVR then provides the user with menu options for retrieving new messages, sending messages, or changing the mailbox feature options. (Feature options are discussed in the section entitled "Voice Mail Usability Features.")

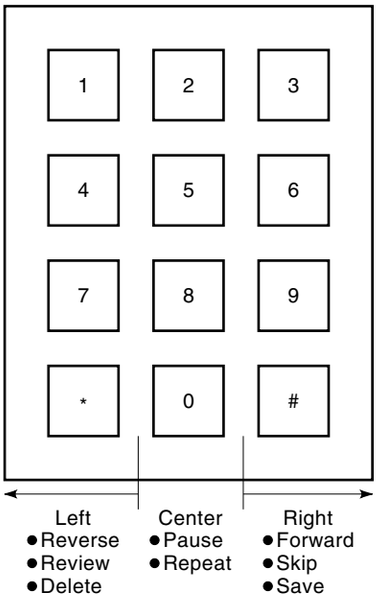

Figure 1. Example of standard telephone keypad with cues for forward/reverse navigation metaphor added.

When retrieving a single message or working with lists of previously saved messages, the user may wish to navigate forward or backward rather than work sequentially through the messages. Current voice mail systems use one of two interface metaphors to organize menu options. The first option is a mnemonic metaphor, where specific commands are mapped to the telephone key with a corresponding letter equivalent. For example, such a system would use "3" to *delete* a message (*D* is on the "3" key), "5" to *keep* the message (*K* is on the "5" key), and "7" to *replay* the message (*R* is on the "7" key).

The second navigation metaphor is based on a tape player model. In this metaphor, buttons to the left of the center column ("1", "4", "7", "*") indicate reverse, review, or delete options. Buttons to the right of the center column ("3", "6", "9", "#") indicate forward, skip, or save options. The center column buttons ("2", "5", "8", "0") indicate pause, additional information, or repeat options. (This metaphor also benefits from the traditional use of "0" for operator assistance.) See Fig. 1 for a graphical presentation of the tape player metaphor.

VOICE MAIL USABILITY FEATURES

Any IT interface must have features that support multiple levels of human capability. These features may be described in terms of *system usability* features and *task utility* features (to be discussed later). System usability features refer to elements of voice mail that are compatible with the physiological, perceptual, and basic cognitive function of the user. Requirements for AVR menu presentation are examples of usability features. All user interactions with the voice mail system are auditory; AVR commands and menu options are presented serially through the telephone handset. Human perceptual capabilities limit the rate and complexity of infor-

mation presented through auditory channels. Compared with visual desktop computer interfaces, voice mail requires much more shallow menu structures (fewer options per menu selection) and more simple commands (requiring one of 12 primarily numeric keys). These restrictions are not a result of characteristics of organizational tasks but instead are the working memory of the voice mail user and the limitations of the telephone keypad.

For a voice mail system to be effective, users must be able to recognize when they have messages waiting to be retrieved. Two methods of electronic message alerting are popular: activation of a stutter dial tone and switching of an alerting light. The stutter dial tone has the advantage of not requiring any additional hardware changes for the user. However, the stutter dial tone is a passive, or "nonindexical," mode of alerting. Users will not know that there is a waiting message until they pick up the telephone to make an outgoing call. (Because there is no dial tone associated with an incoming call, users who simply answers a ringing phone will not be aware of waiting messages.) Therefore, the message-waiting light indicator is a preferred method of message alerting. The additional hardware required is minimal (simply a light placed in series with the telephone line, with an electronic switch that is activated by the voice mail server). Users are much less likely to miss waiting messages because the light is a more active alerting system that does not require specific user interactions for the alert to be presented.

Most voice mail AVR systems open with a standard greeting where the application is identified or the sender is informed that he or she is connected to a user's voice mail box. After this, the control menus that list the options currently available to the user guide the user within the system. Consistent use of a single interface metaphor plus a sensible hierarchical flow structure allows the AVR to handle a potentially large number of commands or functions. User-centered interface design guidelines can aid in developing an effective design and hierarchical structuring of the menu system to enhance usability. Some of these guidelines follow.

Menu Organization and Menu Depth

Users' sensory and working memory limitations place an upper bound of approximately 30 seconds on a single level of menu presentation. In addition, novice users require a straightforward, goal-oriented presentation of command options. These limits usually demand that a single menu level present no more than four options at one time. In order to further facilitate use, menus should be ordered by frequency of use or functional grouping. Functional grouping refers to a menu where similar types of tasks are presented at the same level of menu hierarchy. For instance, commands that operate on the current message should be presented at a single menu level, rather than combine single message commands with global message organization or user preference commands. (The topic of frequency of use grouping is addressed again in the section entitled "Task Utility of Voice Mail Systems.")

In order to be more consistent with the cognitive makeup of voice mail tasks, menus should use the goal–action sequence rather than the action–goal sequence. For example, using the prompt "to delete this message press 7" is more effective than saying "press 7 to delete this message" (2).

Interface Navigation Metaphors

As described previously, voice mail command menus usually incorporate either a mnemonic or directional navigation metaphor. There are several reasons why we strongly encourage the use of a directional navigation metaphor. Language differences between user populations will always limit the effectiveness of a single command mnemonic strategy. For instance, using "5" to save a message (using *keep* as the mnemonic) is difficult for English-speaking users who expect *save* as a computer mnemonic (thus expecting to use "7"), or French-speaking users who expect *gardez* (thus expecting "4"). The directional icons of disk and tape players and recorders are more universal and are therefore less likely to be confused through translation.

From both cognitive and sensorimotor perspectives, telephone-based CMC interfaces are less compatible with alphabetic metaphors. Sequences of numbers are easier to recall than sequences of nonsense letters. Even though words are easier for many users to recall than sequences of numbers, an extra perceptual/motor conversion step is required to translate each letter into the corresponding number in order to enter via the telephone keypad. The organization of the touch tone keypad was developed as an attempt to optimize the combination of speed and accuracy of numeric entry and uses more familiar motor programs for data entry than an alphabetic navigation strategy (3).

Command Usability and User Expertise

Voice mail systems must cater to a mixed population of novice, occasional, and highly experienced users. In order to accommodate skill levels of various users, the system would ideally allow users to pick their own style of command interaction. For example, the prompted directions offered by the system are detailed and take the users step by step through any procedure. For the more experienced users who are already familiar with the menu structuring and commands, this can be time consuming and frustrating. Therefore, the principal menu structure must allow users to override voice instructions or commands at any point by entering the next tone key command. To accomplish this, voice mail AVR systems use features such as dial-through and dial ahead. The dial-through feature allows users to interrupt most system prompts and messages by pressing a key corresponding to their next menu choice as soon as they hear it. They do not need to wait until the system has listed all options at that menu level to enter their choices. The dial-ahead feature in voice mail allows users to enter option commands before the AVR system offers the menu. Both features allow the users to bypass or interrupt menu directions at any time during the command prompting. This serves to make the voice mail system more flexible to work effectively for a range of populations with different levels of experience with the system. For additional detailed voice-messaging standards refer to International Standards Organization guidelines (4).

User Characteristics

User characteristics such as age, gender, and IT experience can influence user acceptance of a CMC system such as voice mail. User characteristics often play an indirect role in system use through differences in task roles and previous learn-

ing patterns. Relatively few user characteristics are directly affected by specific aspects of voice message digitization. Obvious exceptions include the speed complexity of AVR prompts for users without sufficient language skill to understand the AVR instructions. However, the indirect influence of user characteristics on command usability cannot be ignored.

Experience. More experienced users developed a wider variety of uses of voice mail. They are also willing to use it more often to support their tasks. At the same time, the heaviest users of the system were most likely to evaluate the system as being slow, unreliable, and noisy. Novice users needed detailed and clear instructions from the system and rated clarity of help messages. For the more experienced users, these messages were of lesser value because of their familiarity with the system. With increased experience, user ratings of helpfulness and clarity of voice mail prompts declined. This indicates that user expectations and demands from the system change with the amount of time spent on the system.

Age. Learning to operate a new voice mail system was easier for younger users than older users. This may be a result of the knowledge of previous systems that may interfere with the learning of new systems or the influence of age on the ability to learn and adapt to new technical systems. Older workers constitute a growing segment of the worker population, and it is crucial to take into account age-related factors in system design.

In light of these findings, we can conclude that the voice mail system must be flexible enough to accommodate the various requirements of a more general user population. The significant influence of user characteristics on the usability and utility of voice mail emphasizes the need for considering these usability features and interface design characteristics early in the design process.

TASK UTILITY OF VOICE MAIL SYSTEMS

Although physiological and cognitive aspects of feature usability are critical features of voice mail systems, these elements of technology design are not sufficient to ensure effective technology integration. The true value of voice mail, or any information technology, is in its ability to improve productivity and cost-effectiveness of system performance. Effective integration of IT into tasks required by the organization are components of task utility. Navigation metaphors are features that are integrated in the voice mail system and, therefore, are examples of system usability. Sending messages to multiple users simultaneously or responding to other system users via voice mail without dialing their telephones are tasks that a voice mail system may support, regardless of the specific navigation metaphor used. The variety and usefulness of tasks supported by the voice mail system are examples of system utility.

System designers must be responsive to user needs, expectations, and normal patterns of task flows in order to integrate new technologies into an organizational context effectively. Both observations and direct surveys/interviews of potential users are very useful in this stage of technology development. Early integration of user priorities into the IT design provides several major advantages in terms of system costs and performance. System changes that are made during the preliminary design phase are several orders of magnitude less expensive than changes that may be required in the post-production phase. In addition, system update cycles can be substantially shortened by reducing the variance between user skills or task demands and system capabilities. Overall reductions in time to system delivery, change costs, and user efforts to overcome technology incompatibilities greatly outweigh resources devoted to initial user evaluations (5).

System design efforts to improve IT task utility are closely related to the processes of technology adoption and diffusion. Technologies must be acquired before they can be used, and someone must be convinced that the benefits of technology use will be greater than the costs of acquisition. Users must find that the technology is effective for them to continue to use it and recommend it to others. Therefore, improvements in technology design processes are critical to overall success of the voice mail system. Findings from previous user evaluations are presented later as an example of these design and implementation processes, as well as elements of voice mail task utility.

Desirable Voice Mail System Features

As part of the evaluation of candidate voice mail systems in state government offices, Caldwell and Caldwell (6) conducted a survey of voice mail users between December 1992 and March 1993. Included in the survey was a section where users were asked to allocate point values among 19 command features "to optimize your use of voice mail" (i.e., optimize task utility). This survey technique is called ipsative measurement; here the respondent is required to allocate a limited resource among several options in terms of their priorities for having the options available. Approximately 930 users responded to this section of the survey. As seen in Fig. 2, task utility preferences were given to the following voice mail features: time and date stamping of incoming messages, ability to scan through messages, ability to replay messages after hearing them, operator escape functions, and ability to move forward or backward within messages. Each of these options received at least 7% of the point allocations; the first three options each received over 10% of points allocated. The findings from this study should not necessarily be used to assume task priorities for all users. Nonetheless, these findings clearly show the priorities for voice mail command features to optimize task utility among the population of state government employees. In addition, an ipsative survey technique can demonstrate effective functional and frequency of use groupings of feature options (among general options, message sending, playback, and caller access features). Option priorities data can help determine design strategies and identify "suites" of advanced feature options that can be marketed to specialized users at additional cost, while minimizing overall design complexity for the basic voice mail system.

One significant comment from many users of voice mail systems during the trial evaluation period was the importance of having a system that was compatible with, and linked to, voice mail of colleagues, coworkers, and counterparts at other divisions or agencies. These comments highlight how social aspects of the technology diffusion process regulate the success of a computer-mediated communications

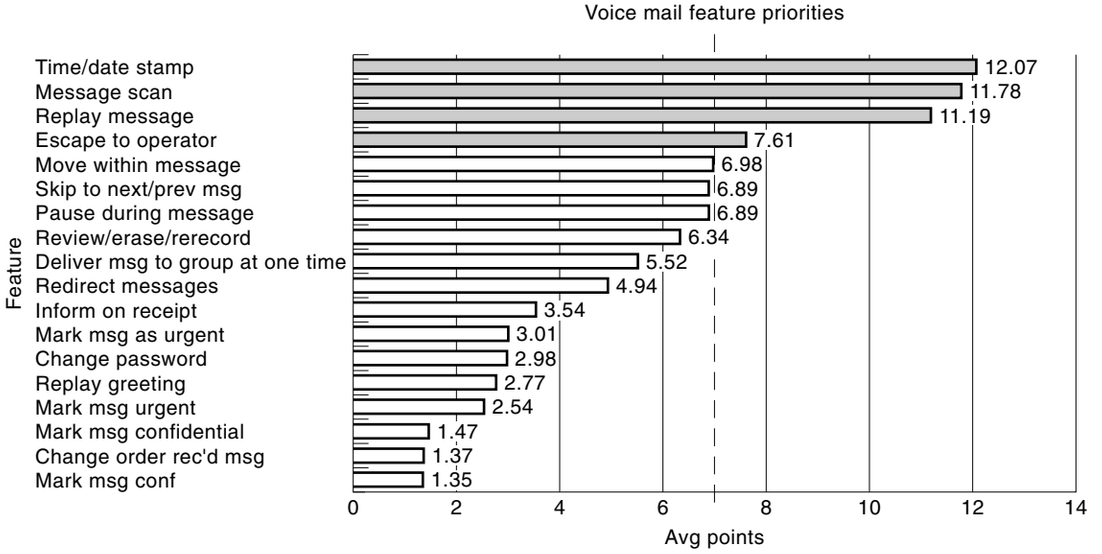

Figure 2. List of preferred features and ipsative point allocations (mean values), state government voice mail evaluation survery, December 1992 to February 1993. Total respondents = 930.

technology. A significant number of users found the technological features of voice mail valuable in themselves. However, many additional users were willing to use voice mail because of their access to other voice mail users in ways not available for nonusers of voice mail.

Because most state government employees in the evaluation survey did not make their own decisions to have voice mail technology available to them, it is important to separate technology acquisition decisions from actual functional use (adoption) and successful spread of system utilization (diffusion) patterns in CMC users. The following sections summarize critical aspects of voice technology adoption and diffusion, as well as important task and technology variables that may limit CMC effectiveness.

TRAINING AND DOCUMENTATION

The Caldwell and Caldwell survey examined users' preferred ways for getting help information to improve their use of the voice mail system. The most preferred source of information was other users, presumably because of the similarities of task contexts and user experiences shared between workers in the same organization. Many of the state government agencies require formal training as a prerequisite for system activation; whereas anectodal evidence suggest that both the primary training and documentation provided by the vendor are not appropriate for user needs.

The emphasis goal-action sequence of presenting voice mail command functions (described in Voice Mail Usability Features) can be repeated here at another level of examination. Even though user training and documentation are frequently organized in terms of feature and function lists based on the engineer's traditional task and project organization (5), users express a strong preference for training in context. (In some cases, actual on-the-job training may not be the most effective or supportable style of user education and information delivery.) Therefore, the goal orientation of users conducting specific voice mail tasks should carry over to the design of training and documentation supplements to the voice mail technology; rather than feature lists, these supplements can be presented in how-to reference or tutorial format, progressing from simple to more complex tasks.

FACTORS INFLUENCING VOICE MAIL EFFECTIVENESS IN ORGANIZATIONS

Voice Mail Adoption and Diffusion

Technology diffusion is described as the process by which a technology is shared and communicated through a social system over time. Research addressing technology diffusion has identified five major factors that affect users' desire to utilize new technology (7): relative advantage, compatibility, simplicity, observability, and trialability. Initial adoption of the voice mail system can depend upon several of these factors.

Relative Advantage. *Relative advantage* is the degree to which an innovation is perceived by users as more useful than the tool it would replace. Voice mail is likely to be compared with message centers, answering machines, and human operators/secretaries. A crucial factor in determining the relative advantage of an innovation is the user perception of the product. Research has indicated that this can be a more significant factor than objective performance measures or technology criteria. The process of diffusion of voice mail will significantly depend upon whether the users perceive voice mail as "advantageous" or helpful in the work environment.

Compatibility. The second factor in successful voice mail implementation is *compatibility*—the degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters. Compatibility has been shown to be a crucial design factor in determining cost effectiveness and user acceptance of new CMC sys-

tems. The purpose and use of voice mail is highly compatible with that of answering machines, a widely used and accepted technology.

Answering machines have also served to familiarize the user with the concept of voice messaging. Present voice mail systems make use of the telephone interface (the keypad on the telephone) for entering different menu options available. Because of voice mail systems' compatibility with previous communication systems and with past experiences of the users, voice mail technology is likely to be easily accepted as a natural extension of past voice messaging capabilities. Task utility design criteria are critical to user perceptions of relative advantage and compatibility. Therefore, a voice mail system is unlikely to be considered acceptable by users if their task utility demands are not met.

Simplicity. *Simplicity* is the degree to which the innovation is perceived to be easy to understand and use. User acceptance of voice mail systems may drop drastically as a result of complex interface commands or task sequences to complete routine tasks. For the user whose tasks require only the basic "answering machine" capabilities of receiving incoming messages, additional voice mail features may be too complex and confusing. The need for perceived simplicity is an important factor influencing the design of command suites and functional groupings of features from basic to advanced.

Observability and Trialability. *Observability* is the degree to which the innovation is visible to others who have not yet used the new technology. *Trialability* is the degree to which an innovation may be experimented with on a limited basis. Successful voice mail implementation is more likely if users are able to use some or all features on a trial basis. If users find that the voice mail system can be effectively integrated with a range of task demands and patterns of activity, voice mail will also provide clearly visible results to them, as well as customers outside of the organization. These features suggest the use of limited-time system-use licenses to determine which users are likely to gain the most benefits from voice mail without providing full functionality (at significant initial cost) to all users immediately.

In the voice mail evaluation survey study described previously, many users cited the large-scale availability of compatible systems with a base of networked users as a major factor influencing their willingness to use voice mail. System designers and technology managers must be particularly sensitive to user perceptions of voice mail task value and productivity because these perceptions both derive from and influence the design of the voice mail interface and range of appropriate task functions.

Patterns of Voice Mail Implementation

Traditional technology adoption research (including CMC adoption) has focused on those criteria that influence the decision to acquire the CMC system. However, for organization-wide CMC technologies such as voice mail, the process of technology adoption and implementation is not complete until the system is effectively integrated into the organization's range of required tasks. There are at least three possible patterns of implementation of new technologies (8,9). One pattern is that of poor implementation, as a result of which productivity either suffers or increases only marginally. A frequent cause of this problem is when CMC technologies are acquired that cannot be effectively integrated with normal organizational tasks. Users willing to use the CMC are forced to release task patterns and work flow to accommodate the technology, at substantial costs in time and production efficiency. It is more likely that users will use the CMC sporadically and ineffectively, if at all. In this case, the CMC technology acquisition costs are completely wasted because the CMC is not used to improve the performance of organizational tasks.

A second pattern of CMC implementation leads to significantly increased productivity through effective incremental process innovations. In the case of voice mail, incremental process improvements can be seen in more reliable, complete, and direct delivery of telephone messages, as well as more secure access to messages from a variety of locations. Finally, the adoption of new technology may be of such great success that it results in the ability to accomplish previously impossible or unimagined tasks. This third outcome, which helps achieve unexpected gains in organizational performance levels, often results from novel and unforseen uses of the technology. An example of a previous innovation that led to novel uses of technology is that of digital electronic ringing. The technology to provide electronic rings using sound synthesizers was initially developed as a method of making lighter and smaller telephones. However, this innovation has led to systems that can provide distinctive rings for users to indicate to whom an incoming call is directed, or even the type of call (when associated with Caller ID information, which is usually available in some form as part of the voice mail user database).

Our longitudinal studies of voice mail usage have demonstrated that voice mail system usage and task integration are not uniform across an organization. Users' voice mail system access (as measured by calls to the voice mail AVR system access numbers) were consistently higher in late morning and mid afternoon and varied across days of the week. These patterns did not change significantly over the course of 18 months of system usage, even though the number of voice mail users grew from 4000 to over 10,000. These findings are important pieces of information for voice mail and other CMC technology designers, who must be sensitive to (and design systems that are responsive to) large variations in system access and response capabilities across a very large range of operating conditions. The wide variations in voice mail use indicate that overall system robustness to widely varying conditions, rather than narrow tuning to ideal performance over a smaller range of conditions, is the true design goal of the voice mail and CMC system designer.

One surprising finding from the longitudinal voice mail use study shows that adoption and system use patterns among new users are not homogeneous. Studies of technology adoption according to Rogers' diffusion criteria often assume the adoption process to be binary, depending solely on making the technology available for users. However, tracking of new voice mail users showed that at least three distinct patterns of users become evident during the first month of technology availability. One group of users began using voice mail substantially (over 10 hours per month) almost immediately. Most users developed modest use patterns, whereas a few users did not use voice mail much at all. (A small group of voice mail

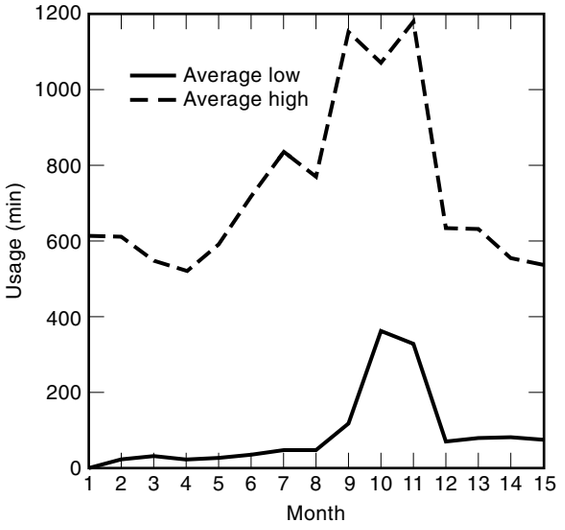

Figure 3. Mean monthly usage (minutes) of top 30 and bottom 30 new voice mail users as of September 1993, tracked until February 1995; state government voice mail telecommunications data.

users demonstrated very significant seasonal patterns of voice mail use, with extremely high levels of use in some months and little or no use in others. This group may be described as a group of situational users, where the situational factors affecting voice mail task demands varied on an annual, rather than a weekly, basis.)

Figure 3 illustrates the differences in usage between the highest 30 and lowest 30 users in the first month of voice mail availability. Notice that the initially high voice mail users consistently access the voice mail system heavily throughout the 18 months of the study; initially low voice mail users remain low in usage over time. Patterns of use that developed early on in voice mail availability remained fairly constant across the population. A total of 244 users first received voice mail in the second month of the evaluation period (September 1993). Of the 27 new users who were among the top 10% of voice mail users in that month, 20 of them were among the top 10% of voice mail users in the last month of the evaluation (February 1995). Only three of the users who were in the top 10% of voice mail users in September 1993 had dropped to the bottom 10% of users in February 1995. Only nine new users among the bottom 10% of users in September 1993 had grown to be among the highest 10% of users in February 1995.

These results indicate that effective task integration and functional utility of voice mail can be discovered quite early in the user's experience with the new technology. Users for whom voice mail task utility is initially high will very quickly adapt patterns of task performance that are compatible with the capabilities of the voice mail system. Matches between user needs and voice mail command usability and functional utility have a strong and rapid influence on the ways in which the voice mail system is used in the organization. Several user and organization factors will make distinctive contributions to CMC performance beyond those of technology design variables. The following section describes how these nontechnology factors are responsible for major constraints on voice mail system performance in real-world task environments.

USER CONSTRAINTS ON VOICE MAIL SYSTEM PERFORMANCE

Even an information technology with ideal physical function and command usability may suffer from disuse of user frustration if it does not possess task utility for its users. In a large organization, the range of users and necessary tasks indicates that no "one size fits all" CMC system will support all users equally. Therefore, task variety and task constraints, as well as differences between users, will significantly affect how well a CMC will be integrated into the acquiring organization.

Some user and task constraints between members of the organization are relatively fixed and therefore easy to integrate into CMC technology design and managment. For example, field sales forces are less likely to be at their home telephone than clerical staff and, therefore, more likely to have high voice mail usage. Accountants are likely to have specific questions requiring detailed numeric responses (which would be difficult to convey in a secretary-transcribed message). Upper-level project managers, on the other hand, may receive and send more general messages regarding project status, due dates, or changing task requirements.

Other types of task constraints have a much more dynamic, but no less critical, influence on voice mail effectiveness and task utility. Impending deadlines, unexpected difficulties or task requirements, or novel information demands can all influence messages sent via CMC. Because these task constraints are not uniform over time, system performance that is acceptable in one set of situations can be intolerable in another. A component of the Caldwell and Paradkar voice mail evaluation survey was an examination of the influence of situational factors on users' tolerance for technology-based voice mail message delays (10). The situational factors studied were message urgency (time urgency of message delivery), message content (volume content of message), and distance (distance between the sender and the receiver).

Study results indicated that time urgency had a major impact on users' tolerance for delays related to voice mail system performance. The other situation factors of message content and caller-receiver distance also had significant influences on users' acceptance of voice mail system delays. Users were more tolerant of degraded system performance when messages were less urgent, longer, or came from a more distant caller. (More distant callers, in particular, have fewer alternatives for contact; users seem to take these factors into consideration when evaluating system performance.) In addition, there were significant interactions between user characteristics and situation-based task constraints. The impacts of voice mail technology capabilities on users are discussed further in the following sections.

Impacts of Degraded System Performance on Users

Poor technology implementation, especially voice mail and CMC systems that are incapable of handling the intended "success" of increased system usage, can have a catastrophic effect on workplace effectiveness and employee health and productivity. Truly evolutionary CMC implementation and adoption occurs when the CMC is used heavily by a number of users, and moderately by a large fraction of potential users, showing new communications processes and potentially radi-

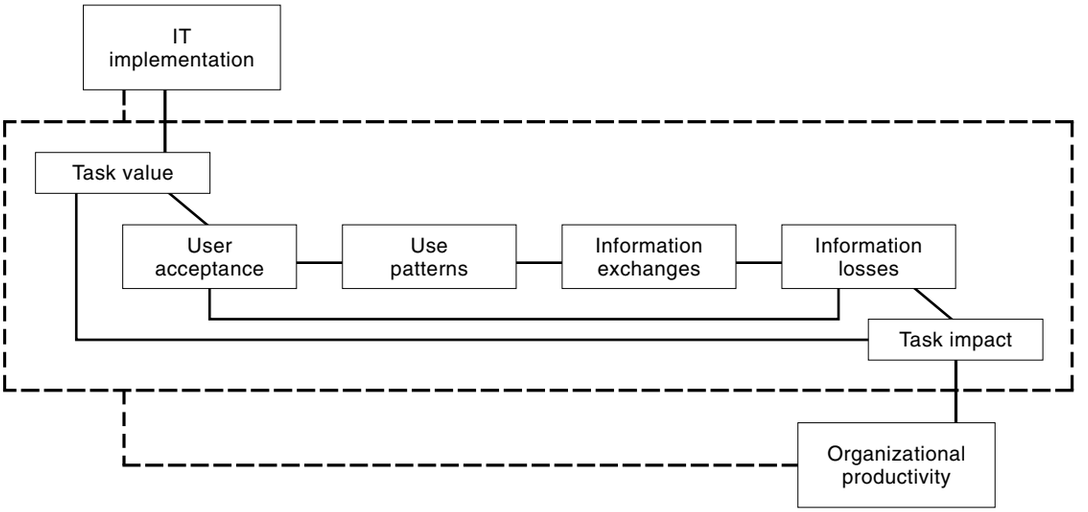

Figure 4. Conceptual diagram of information technology implementation and organizational productivity processes in organizations, including task value/task impact feedback loops. Note the negative feedback loop from user information losses due to delays and user acceptance of technology, and loop from organizational productivity to information technology implementation.

cal changes in ranges or distributions of organizational tasks. In this case, the new CMC has been so well integrated that it becomes a critical part of the work system for a number of employees and enables them to complete tasks previously impossible or impractical to accomplish. (As previously discussed, not all employees will adopt and integrate the new technology at equivalent levels because of the variety of tasks they perform.) The potential drawback to this type of successful technology implementation comes when new system capabilities and improved communications flow become the new norm for expected levels of performance (11). Increased use of the voice mail system will necessarily increase the demands on the technology infrastructure, as shown in Fig. 4. Voice mail and associated CMC technology must be designed to accommodate the increased system load with minimal effects on system response time and reliability.

CMC system breakdowns or technology performance degradations have a more catastrophic effect on organizational productivity in settings where the CMC has been strongly integrated into the patterns of organizational task performance. In addition, system breakdowns and slowdowns are a significant detriment to the mental and physical health, and timely and effective task performance, of users within the organizaton. The effects of complete system breakdown are obvious. However, the impact of voice mail message transmisison delays is less evident to many technology designers. The next section describes how users are affected by delays in message transmission as a result of system loads or poor technology implementation.

Sources and Types of Voice Mail Delays

The rate of information exchange is a significant design factor in the evaluation and implementation of any new CMC technology. Although new CMC systems promise close to instantaneous message delivery and data transfer, technological constraints can cause problems in transmitting and receiving information. CMC systems are subject to two types of delays: information transmission delays (lags before a message is delivered) and information presentation delays (restrictions in flow rates reducing the effective communication rate once message delivery has begun). Every communication system has a natural transmission delay time associated with it. For example, physical mail delivery can take up to several days, whereas electronic mail is expected to be delivered within seconds or minutes. This time can be defined as the natural transmission delay time associated with the system. This delay time is governed by technology infrastructure capability (such as number of links between sender and receiver, and minimum delays or bottlenecks at each node). In addition to these delay baselines, system load, system malfunction, or system failure can affect transmission and presentation delays in a continuous and situation-dependent fashion.

In the case of voice mail, message transmission delays are primarily affected by the response capabilities of the voice mail AVR and system response times of the computer network servers. For example, a user may just miss an incoming telephone call as it is captured by the voice mail server AVR. In this situation, the minimum wait before they are able to retrieve the message is dependent on the length of time it takes the AVR to prompt the caller through any interface options, the length of the message, and the time before the user's voice mailbox is updated and an alert is sent to the user's telephone. Clearly, the AVR and message-recording delays are measured in seconds (if not tens of seconds). When system loads are high on a large voice mail system, mailbox updates and user alerts may be measured in terms of minutes. During system repairs, upgrades, or unplanned downtime, delays of hours or days in mailbox access are possible.

Voice digitization technology has reached a point where message presentation delays are rarely a consideration in telephone switching networks. Telephone networks have been designed with sufficient bandwidth capacity to carry multiple simultaneous analog conversations. Human speech is primarily concentrated in frequency bands between 500 and 4000

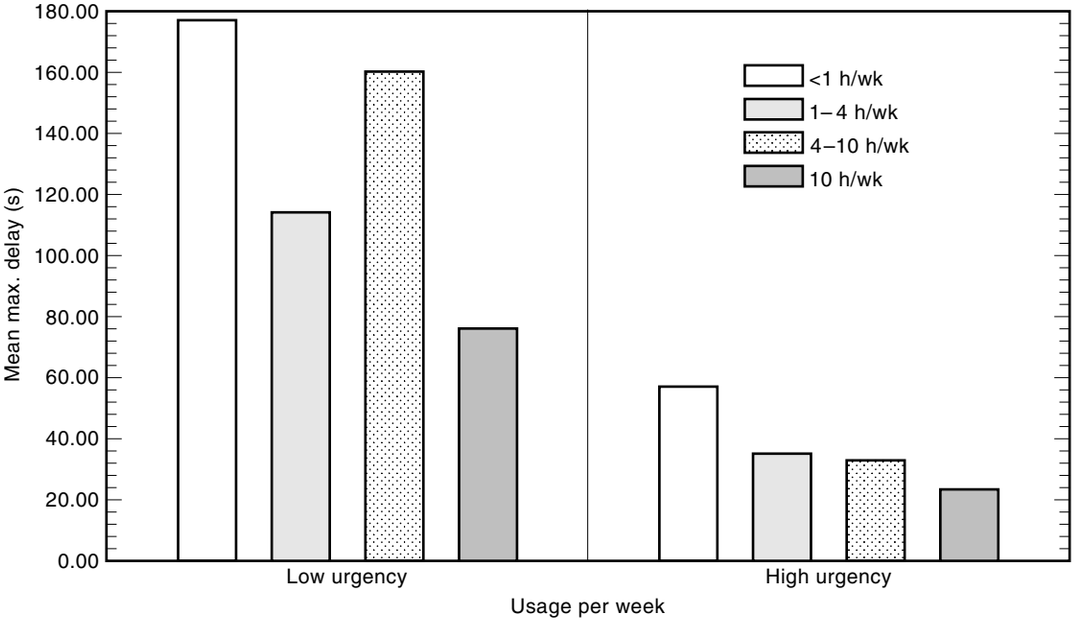

Figure 5. Graph of relationship between situation constraint of task urgency and user characteristic of frequency of use per week, state government voice mail evaluation survey. F-Ratio (df = 3,882) = 3.96; p = .008.

Hz; reasonable voice message fidelity is achieved at one-dimensional, monaural sampling rates of 8000 Hz. Data storage requirements for voice digitization are modest: voice mail messages rarely exceed one minute, or 480 kilobits (kb). These requirements are well within the capabilities of signal processing and data storage hardware available in low-end consumer products. Message transmission delays are therefore a more significant design challenge for voice mail technology development than message presentation delays.

Factors Affecting User Tolerance of Voice Mail Transmission Delays

Users may choose a certain communication system because it promises to be faster than the one they currently use. However, the users' tolerance for delay from the system will be affected by factors independent of the technology itself. It can depend upon situational constraints as well as user characteristics similar to those already described. The influence of situational constraints on the maximum amount of time that a user is willing to wait to have a message delivered or received (defined as the maximum tolerable delay) has been evaluated through a survey analysis (10,12).

In addition to these situational factors, user characteristics also significantly affected delay tolerance of the users. User experience as defined by the number of hours spent on the system was more significant than the amount of time the person had access to the system. With increasing experience, user tolerance for message transmission delay decreased. Users who utilize the system more heavily are those with the narrowest tolerance for system acceptance. Age of the user also had an effect on delay tolerance. Younger users reported a lower tolerable system delay across the range of task situations than older users.

In some cases, combinations of user characteristics and situation variables greatly influence ranges of acceptable system performance. Overall, heavier users were less tolerant of delays in voice mail message transmission. Users were also less tolerant of delays in urgent tasks (i.e., tasks with impending time deadlines). The interaction of user's usage level and task urgency was also significant: heavy voice mail users became less tolerant of system delays during urgent tasks than light users. This relationship is shown in Fig. 5.

SUMMARY

Voice mail represents a class of computer-mediated communications technologies to support asynchronous telephone information flow between callers and receivers. Voice mail systems combine automated voice response technologies with voice digitization and command-based function interfaces using the telephone keypad. Even though digitization and voice synthesis technology advancements may change underlying attributes of voice mail messaging capabilities, a number of supplemental factors will strongly affect the design, implementation, and ultimate success of voice mail systems.

The design of the voice mail keypad interface will strongly influence users' capabilities to send and retrieve messages through the system. Interface design must acknowledge both command usability concerns (based on users' sensory and functional limitations with auditory information) and task utility demands (based on functional task demands associated with organizational information flow). Voice mail usage levels can be expected to vary substantially in daily, weekly, and annual cycles of system accesses. Access cycles affect system performance in terms of server load requirements and delays in message exchange. These delays are of two forms: trans-

mission delays (delays between the caller attempt to reach the receiver, and the receiver's actual ability to retrieve the message) and presentation delays (delays in the retrieval of the message itself after it has begun to be accessed). Message transmission delays are affected by AVR prompt lengths, menu organization, and mailbox-alerting features. Message presentation delays are affected by telephone system bandwidth and voice digitization capabilities. Technological state-of-the-art telephone switching systems have basically eliminated problems of message presentation delays; however, situational factors and interface designs still create unavoidable delays in message transmission delays.

Voice mail systems should be designed to minimize delays related to system load, and require interface design options (dial-through, dial-ahead) to minimize delays resulting from users' navigation through the interface. The voice mail system requires a robust and flexible interface and AVR technology design to respond to a wide range of user characteristics, task demands, and situation constraints. Interface flexibility through command suites and functional compatibility across organizational tasks are more desirable design goals than a single design to meet all users' needs, or highly specific systems only appropriate for narrow ranges of users or functional tasks.

Related Articles

Other articles in this encyclopedia on related topics include articles on BEHAVIORAL SCIENCE COMPUTING and HUMAN RESOURCE MANAGEMENT. The interested reader is directed to these articles for other discussions of "nontechnology" factors in human-computer or human-machine interaction.

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VOLTAGE COMPARATORS. See COMPARATOR CIRCUITS.

VOLTAGE CONTROLLED OSCILLATORS. See MICROWAVE FERROELECTRIC DEVICES; VARIABLE-FREQUENCY OSCILLATORS.

VOLTAGE-FREQUENCY CONVERTERS. See HARMONIC OSCILLATORS, CIRCUITS.

VOLTAGE MEASUREMENT. See ELECTROMETERS.