NBS TECHNICAL NOTE 732

A Computer Terminal Network For Transparent Stimulation Of the User of An On-Line Retrieval System

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Siegfried Treu

A computer terminal network to enable "transparent stimulation" of the user of an on-line retrieval system has been designed, implemented, and pilot tested. Its basic purpose is to provide a suitable and effective framework and methodology for experimental identification/validation of those human characteristics which should be recognized/reinforced in man-computer interface design. The rationale behind the transparent stimulation approach is presented and the methodology employed for such real-time, unobtrusive scanning and manipulation of the man-computer dialogue is described. A general overview of the hardware and software features of the implemented stimulation network is included.

Key words: Computer terminal network; human characteristics; interactive information retrieval; man-computer interface; transparent stimulation; unobtrusive monitoring.

1. INTRODUCTION

While man's communication with other men often defies rational explanation, the study of man-computer communication should be comparatively easy. In the latter case, an interested third party (or observer) can at least impose a degree of control on the non-human half of the communicating pair.

Nevertheless, more than a decade has passed since Licklider's widely quoted paper[1] on "Man-Computer Symbiosis," and we must certainly acknowledge that the goal of adequately understanding such a complementary relationship remains elusive. That is not to say that no progress has been made, but rather that much more research and experimentation is essential.

A sample selection of references to the open literature can briefly characterize what has been accomplished so far. The need for human factors research in conjunction with computer systems has been variously recognized and discussed (e.g. Mayer[2], Parsons[3]). Different modes of interacting with the computer have been compared experimentally (e.g. Sackman[4]), as have different types of interactive terminals (e.g. Carlisle[5]). Probably more attention has been focussed on a computer's response time to various user requests than on any other measure of interactive computer performance (e.g. Carbonell et al[6], Miller[7], Cordaro and Chien[8]). While response time seems to have a definite bearing on user satisfaction, certain other characteristics are also indicated by collective results of experimental studies conducted thus far (as reviewed by Sackman[9]).

Some researchers have attempted theoretical characterization or modelling of man-computer problem-solving (e.g. Horman[10]). Others have taken a deliberate laboratory approach of providing a research staff with innovative, interactive hardware and software tools intended to facilitate communication (e.g. Engelbart and English[11]). So, the man-computer interface has not been neglected as such. Our increasing awareness of it is obviously highlighted by the fact that a complete chapter (Bennett[12]) will be dedicated to it in the 1972 Annual Review of Information Science and Technology.

But many of the human characteristics which should be reinforced at the interface are either not yet identified or not experimentally verified. This is partly due to the lack of suitable and effective methodology. With this in mind, the author* designed, implemented and tested a computer terminal network enabling "transparent stimulation" of a user during his interaction with a computer. This Technical Note describes the resulting seven-month project.

Emphasis is on presenting the rationale behind the stimulation approach and on portraying the various requirements for such a network. Only a general overview of the hardware and software characteristics is provided. The more voluminous details are described elsewhere in an internal NBS report. An outline account of the transparent stimulation approach is also available from a 1971 AFIPS Workshop paper[13].

2. RATIONALE BEHIND THE STIMULATION APPROACH

2.1 Need for Interface Improvement

It is a commonly acknowledged fact that computer systems in general, and interactive computer systems in particular, have usually been designed by computer specialists who were far more interested in taking advantage of the technical capabilities of the system than in meeting the requirements of the human user. Thus the user-computer interface has been relatively neglected, at least from the user's point-of-view. We may have considerably better typewriter-like terminals available now, and more and more users are gaining access to various types of graphics terminals. We may also have much more effective interactive software available to the on-line user. But that still leaves us far short of the interface improvements which may be possible if we could only learn to understand and verify the natural human characteristics which should be complemented or reinforced at the interface with a computer, and which should consequently be incorporated in further iterations of interface design.

If both the need and potential for interface improvement are indicated, how is it possible to arrive at a definition of those elusive human characteristics which must be taken into account? Should we ask the users for their opinions?

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*While on an NRC-NBS Postdoctoral Research Associateship in the NBS Center for Computer Sciences and Technology (CCST) with leave-of-absence from the Department of Computer Science, University of Pittsburgh.

2.2 Questionable Dependence on Users

Supervisors of computer users normally are (or should be) interested in how productive the users are (or could be) when interacting with computer systems for various purposes. From that standpoint, it may be that a user should not necessarily be provided instantaneous response time, for example, in order to be most effective. Perhaps, as considered by Boehm et al[14], a "lockout" or deliberate delay in response can enhance the problem-solving thought processes required for certain computer-aided tasks. The user may be frustrated by such delays, but he might be more productive.

On the other hand, since we live in a society in which the rights and well-being of the individual should be important, we should reckon with that individual's preferences in the context of computer assistance. This does not have to be detrimental to productivity, since we know that an interdependence, albeit very complex in nature, between productivity and human satisfaction exists. If we want the computer user to be both effective and satisfied, we should consider him personally to be a valuable source of data for experimental determination of his levels of effectiveness and satisfaction.

But how should this source of information be tapped? Conventional questionnaire and interview techniques have frequently been used in the past. These have, however, been variously criticized (especially in the area of information storage and retrieval) as amounting to opinion polls of questionable dependability. Humans are, after all, recognized as having numerous inconsistencies, memory failures, biases, etc., which tend to have strong bearings on how they might fill out a questionnaire.

At another extreme, a user's subjective responses could be altogether evaded by making physiological measurements on him during his interaction with a computer. In this manner, the user's fluctuations in emotional response (e.g. indicated by rate of heart beat), as precipitated by "computer system behavior," could be correlated or compared with known symptoms of frustration, happiness, etc. It is not clear, however, that the average user (especially when serving as an experimental subject) becomes emotionally affected enough during his interaction with a computer to provide physiological indicator values which could reliably discriminate among different levels of satisfaction. Nevertheless, this technique might become useful at some time in the future, especially when applied to computer users during periods of real-life crises. At least it could serve to verify subjective verbal responses, or vice versa. For purposes of this transparent stimulation project, however, its application was neither considered feasible nor desirable.

One more major approach to gaining meaningful data about user-computer interaction is to monitor and/or observe that interaction. As discussed in the next section, the necessary choice is between doing so either actively or passively.

2.3 Active versus Passive Monitoring

Passive monitoring of a user-system dialogue affords the collection of data about what the user in fact experiences (in terms of response time, system functions, etc.) as he makes various demands within the limitations of the particular system's capabilities. However, it does not lend itself to gaining the corresponding levels of user satisfaction and requirement, except by implication (e.g. if he uses a certain feature often enough, he seems to like or need it).

Part of the problem could be resolved by passive monitoring complemented by an on-line facility for questioning a user about his current level of satisfaction, immediately after a significant system response has occurred. In this manner, any wants or needs implied by the collected data on actual user demands could at least be verified (or refuted) by a user's personal judgment, taken immediately after the event of concern and thus at a comparatively advantageous point in time (within the user's span of short-term memory).

But this semi-active monitoring approach still has its problems. A particular system is by design limited to a certain type of response under a certain set of circumstances. The number and nature of alternatives in a system response at any time is, therefore, quite restricted. If we happen to be interested in studying and redesigning the entire man-computer interface, based on the spectrum of pertinent human characteristics, we must have greater flexibility and versatility in what takes place at the interface.

This is where active monitoring and observation, herein called "transparent stimulation," comes into play. To test a user's reactions to various alternative system responses, we must be able to stimulate him by causing alternate, preplanned system responses to occur at the appropriate times. This stimulation can be made contingent on a combination of software scanning and human (observer) monitoring of the dialogue. It must of course be unobtrusive or "transparent" to the user, if at all possible. And it must be coupled by the already described mechanism for requesting and receiving on-line indications of user satisfaction or emotion.

Should the monitoring and stimulation capability be implemented by modifying the object computer system itself, or by utilizing a separate, intermediary processor? Because of the prominent arguments against manipulating an operational system for research purposes, it is currently preferable to employ a totally separate research-oriented computer, if such is available. Such a computer system can then be operated as an "invisible" intermediary between user and object system, with no perturbing effects on the latter.

One might furthermore ask why the available research-oriented computer is not also employed as the object system itself, thus precluding any need for accessing an operational system. This alternative is generally not feasible because the research computer may be incompatible with or inadequately equipped to satisfactorily perform all of the functions of a real object system and because of the added complexities of having to simulate real-life operational services. As these answers indicate, the costly local development of representative retrieval software for research purposes appears to be an even less desirable approach.

2.4 Selected Computer-Assisted Task

Any intention to manipulate or modify a user-system interaction surfaces the requirement of having to analyze, in great detail, the peculiar features and functions of the system (and its software subsystem(s)) being used. This in turn brings out the well-known differences in system design based on differences in computer-assisted tasks. On-line computer programming (sub)systems, for example, are quite unlike on-line information retrieval (sub)systems, which are unlike computer-aided design (sub)systems.

Although the transparent stimulation approach should be applicable to other computer-assisted tasks, the anticipated complexities and time constraints clearly may demand selection of and focus on just one. For this project the choice was on-line information retrieval. It was made because of the author's particular interest in that field and also because of comparatively easy availability of one or more such systems.

2.5 Establishment of Design Criteria

What information about the user should the innovative designer of an on-line retrieval system have in order to develop and apply criteria for improved interface design? At a minimum, he should be informed of the human characteristics of which he should take advantage or which he should reinforce. Particular characteristics may be applicable to on-line information retrieval, but they may also apply more generally.

In the already referenced paper about the conceptual framework for the searcher system interface[13], a set of twelve such characteristics were described and summarized as follows:

Designers of interactive search systems, in purposely planning for an effective searcher-system interface, must deliberately take into account that the human searcher has a sense of (or need for):

1. Spatial reference (or perspective)
2. Order (or file arrangement)
3. Completeness (or comprehensiveness)
4. Association (or connectedness)
5. Simplicity (or clarity)
6. Accessibility (or convenient access)
7. Responsiveness (or prompt reaction)
8. Control (or manageability)
9. Versatility (or variety in means and modes of access)
10. Compatibility (or harmony among means and modes of access)
11. Reliability (or confidence)
12. Support (or advice and assistance-on-demand)

These asserted characteristics (and others that could possibly be added) can be looked upon as subject to experimental confirmation or rebuttal. They (or a subset of them) can represent the core of an experimental hypothesis. However, they must first be embodied in a set or sequence of actions, or stimuli, which after presentation to the user will elicit confirming or refuting responses.

If such experimental work can convincingly confirm or refute one or more of the above assertions, then the interface designer should be better prepared to establish criteria for improved design. The transparent stimulation project is intended to be one step, however small, in that direction.

2.6 Characteristic Stimulus-Response Patterns

Based on the reasoning behind the transparent stimulation approach presented thus far, three important actions are seen to be subsumed:

1. the user-system dialog is monitored and observed

2. the user is variously stimulated

3. the user is prompted to request or react with not only

    a. the normal system-oriented message, but also, whenever specifically asked, with

    b. an indication of current level of satisfaction as well as

    c. reason for that satisfaction level

Since the fundamental question of interest is "What does the user do, and how does he feel, as a consequence of the presence or absence of a certain characteristic in a system action?", we are faced with trying to handle stimulus-response (S-R) pairs in the context of man-computer interaction. Consistent with the abundant literature in behavioral psychology concerned with stimulus-response behavior (e.g. Kimble[15]), we consider our experimental subject, namely the human user, to be the object of the stimulation.

The computer hardware/software is then responsible for presenting the appropriate stimuli to the user, and the user in turn generates the responses. Although this viewpoint is contrary to the computer scientist's usual way of considering the response as coming from the computer, it is purposeful in that our priority focus is on studying user (not computer) behavior.

This approach lends itself to the following characterization:

Let S = a stimulus generated by the on-line retrieval system itself

S_a = an artificial or alternate stimulus generated by the intermediary stimulation system or the human observer

R = an original user request or a user response to a stimulus (S or S_a)

R_e = a user indication of stimulus-related satisfaction or emotion

R_r = a user indication of reason for that satisfaction or emotion

then the data patterns of interest are shown in Table 1.

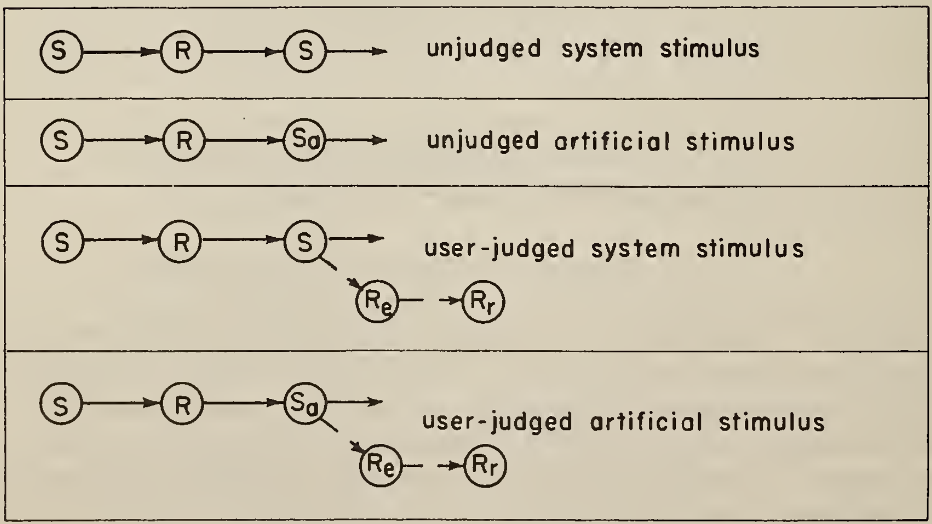


Table 1. Characteristic Stimulus-Response Patterns

To prove or disprove an experimental hypothesis about user behavior, these data patterns must be properly planned, collected and then analyzed. Such patterns can conceivably be embodied in more complicated S-R patterns to be detected or observed in the communication channel between user and system, with an accompanying increase in the complexity of rendering them logically (or psychologically) meaningful and useful.

3. OVERVIEW OF NETWORK IMPLEMENTATION

3.1 General Framework

Before continuing with a presentation of how the characteristic stimulus-response patterns are in fact ascertained and then utilized, it seems appropriate to provide a general overview of how the stimulation network was implemented. As stated in the introduction, most of the pertinent details are covered in a separate report.

The transparent stimulation project, as conceived and implemented, was strongly influenced by capabilities which were in the process of being developed by the Computer Systems Section of the CCST. In addition to integrating a set of networking commands[16] into the operating system software of the locally available time-sharing system[17], thus enabling an applications program to set up network-like communication with a number of different devices via various interfaces, the Section was also preparing a "dialogue monitoring" capability[18]. The latter allows a user to dial into the local (intermediary) computer system which then assists him in establishing communication with the remotely located time-sharing system of interest to him. The intermediary system subsequently monitors and records the entire user-system dialog and, in so doing, collects and analyzes various data (such as response times) significant to an evaluation of user demands and of the remote system's performance.

The above-mentioned networking capability is an essential contributor to the functioning of the applications software for transparent stimulation. The concept of dialog monitoring is clearly related to that of monitoring the dialogue and, whenever warranted, stimulating the user by means of inconspicuous intervention or interjection of variable messages and functions. The main difference is that the stimulation framework involves deliberate manipulation of the interface.

The principal constituents of the stimulation framework are the following:

1. A user - the person wishing to use an interactive computer system for purposes of accomplishing one or more information retrieval tasks.

2. An observer - the person who is situated and equipped to observe or monitor the user-system interaction and who initiates selected stimuli whenever appropriate.

3. An intermediary system - the system or subsystem programmed not only to assist the observer, by means of message interception and processing, but also to complement him by initiating certain stimuli on its own.

4. An interactive retrieval system - the computer system which is available to assist the user in carrying out his information retrieval task(s).

After the user and the observer are each provided with an appropriate terminal station, communication among the four systems or devices is established as shown in Figure 1. The figure not only portrays the communication flow but also the various functions which are carried out within the transparent intermediary system. The design includes two major modes of transmitting messages between the user and the retrieval system. The first mode simply enables a message to be buffered and then forwarded. This is indicated by the dashed arrows. The second mode (solid arrows) provides the capability of buffering a message (from user or system), scanning it and attempting to match it against stored key word tables, and then taking further action depending on the result. In case of a miss, the message is simply forwarded. In case of a hit, it must first be ascertained where in the pre-established S-R-S hit pattern the interaction currently stands. If a complete S-R-S hit pattern has not yet been detected, the stimulation mode is continued by forwarding the current message. If such a pattern has been detected, alternate action is called for.

This alternate action can take three basically different forms. By calling on a selection of action subroutines, the intermediary system can:

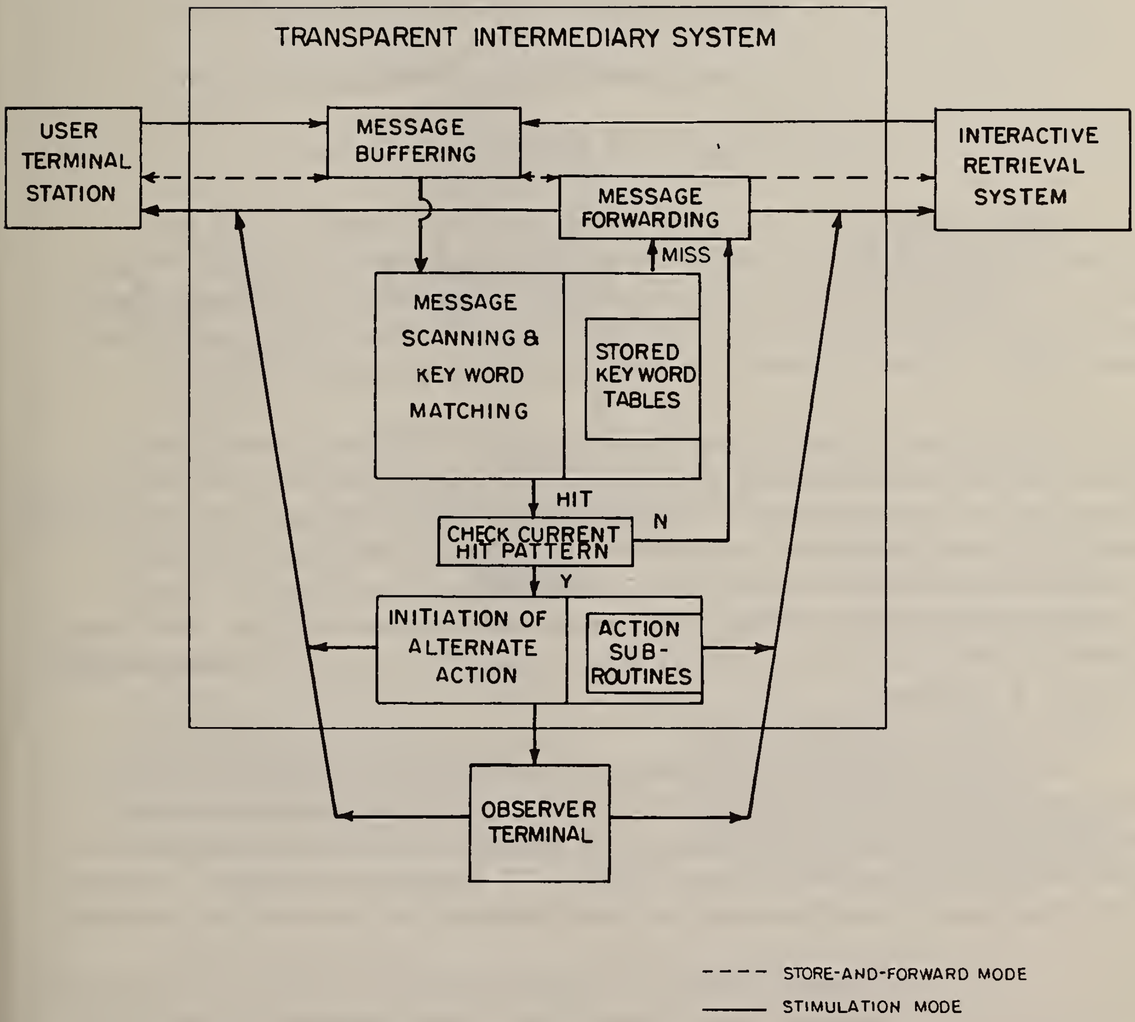


Figure 1. General Functions of the Intermediary System

1. Transmit a specific command to the remote system, which will in turn initiate a new stimulus

2. Transmit a specific command or question to the user, thus in itself presenting a new stimulus

3. Request the observer to input a message, thus requiring him to initiate a new stimulus, in either of two forms:

    a. Direct command to the remote system

    b. Direct message or question to the user

3.2 Hardware and Software Features

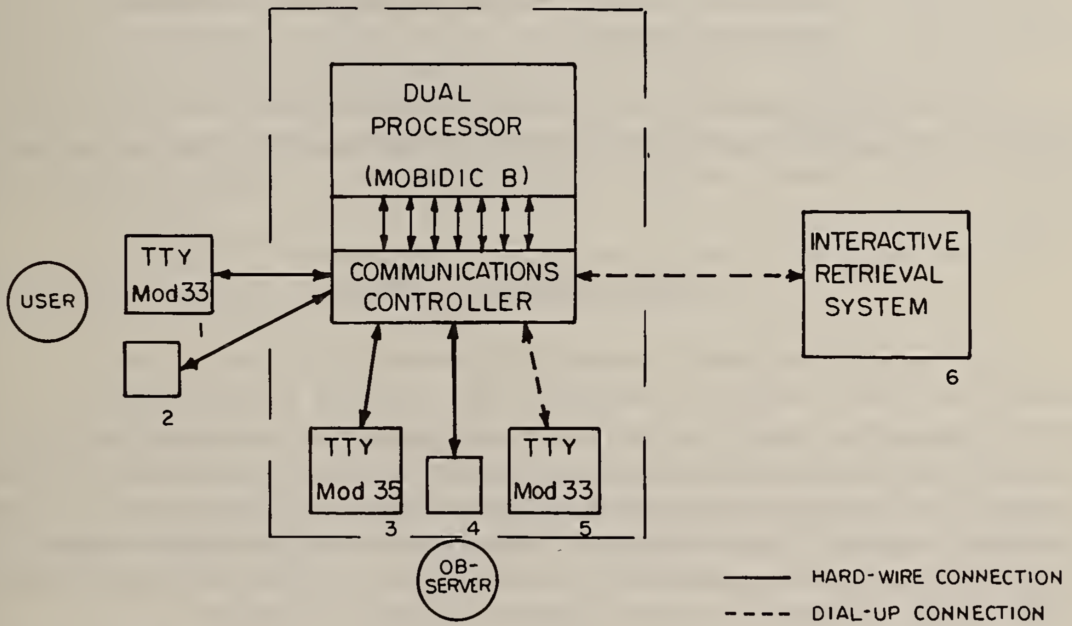
The MOBIDIC-B research computer was employed as the intermediary processor node in the stimulation network. The other nodes are represented by several teletype terminals, two specially constructed devices, and the remotely located information retrieval system itself. This hardware configuration is pictured in Figure 2.

The research facility operates under the locally developed SUPER-CORD Time-Sharing System[19] which supports such software processors as an assembler, a BASIC compiler, and the CL6 compiler[20]. Although it lacks effective character string manipulation, the CL6 compiler was selected as the most suitable for this project. Hence the entire applications software package was written in CL6, utilizing whenever appropriate the system networking commands[16] implemented by Robert Rosenthal.

In order to enable generation of previously described stimuli, contingent upon the occurrence of a certain user response (R) to the standard system stimulus (S), a set of seven action subroutines were defined and implemented as part of the CL6 software package. These subroutines have the following functions within the stimulation network:

1. Transmit Observer Message from Observer Terminal (Device 3 in Figure 2) to User Terminal (Device 1)

2. Transmit Observer Message from Observer (Device 3) to Remote System (Device 6).



Terminal Devices:

1. Standard User Terminal
2. Specially Designed "Satisfaction Level" Prompt & Response Device
3. Observer Terminal for Software-Controlled Output of Selected Data
4. Specially Designed "Satisfaction Level" Request & Display Device
5. Complete (Hardware-Enabled) Monitor of the User Terminal (No. 1)
6. Remotely Located Retrieval System

Figure 2. Hardware Configuration of Stimulation Network

3. Transmit Software-Selected Message to User Terminal

4. Transmit Software-Selected Message to Remote System

5. Transmit User Message from User Terminal to Observer Terminal

6. Transmit Software-Selected Prompt to Observer Terminal

7. Software-Controlled Set of Emotion Indicator Device (Device 2)

Because this applications package requires the maximum available user partition (20,480 words of 36 bits each), the research computer must be employed on a dedicated basis in supporting the project.

3.3 Special Indicator Device

Two special devices, numbered 2 and 4 in Figure 2, were designed and constructed for purposes of providing a mechanism whereby the human observer (or the supporting software) can request and receive on-line indications of the user's level of satisfaction (with the immediately preceding system action) as well as the user's associated reason. The electronic componentry and terminal shells for these devices were specified and assembled by Mr. William Truitt and Mr. James McNally of the Computer Systems Section.

The devices are purposely simple to operate. The user's keyboard has a prompt light at its top and two vertical columns of seven labelled buttons. Whenever the prompt light is lit, the user is asked to push one of the left column of buttons to indicate a level of satisfaction and then one of the right column of buttons to give an associated reason. The observer's special device is quite similar in surface format except that he has a prompt button where the user has a light, and he has two columns of labelled lights which are lit after and in correspondence with the buttons pushed by the user. The observer can thereby gain immediate visual feedback on current user level of satisfaction.

4. ANALYSIS OF REMOTE SYSTEM CHARACTERISTICS

4.1 Selected System

Many incompatibilities which are well know to exist among different computer (hardware and software) systems, are also prominent within the class designated on-line information retrieval systems. Most of them have different sets of commands, communication conventions and so forth. For this and certain other constraints (e.g. local terminal capabilities), it was necessary to select and utilize one particular system. After fairly extensive consideration, the choice was the National Library of Medicine's AIM-TWX System. That system offers a good set of interactive commands, representative of many retrieval systems, and displays desirable consistency in communication conventions as well as interaction language. It furthermore is accessible from standard teletypewriters through the direct dial network.

The AIM-TWX System is fully described in its user manual[21] and, to some extent, in a recent publication[22].

4.2 Message Format Modules

The interaction language for AIM-TWX had to be carefully analyzed. In order to carry out a character-by-character scan (and match) of the messages transmitted between user and system, it was essential to not only identify delimiting characters but also to find any consistently recurring character string sequences or format modules.

This interaction language analysis, based on available sample printouts and aided by the previously mentioned dynamic dialog monitoring facility, led to the format module definitions shown in Table 2. AIM-TWX displays very helpful consistency in (almost) always preceding a system message with the word PROG:, and by (almost) always prompting the user with the readiness cue USER:. These two format modules are labelled S1 and S4 respectively. If we define a "format module" to be a detectable component (character string) of a transmitted message, then a "module sequence" can be regarded as a detectable succession (or string) of format modules perhaps interspersed with variable-length, non-significant character strings.

SYSTEM STIMULUS MODULES		USER RESPONSE MODULES	
S1	L_F | PROG:	" | ~ Command ~ "C_R	R1
S2	L_F | SS □	/ | ~ Command ~ C_R	R2
S3	□~ System Request ~	~ Set of Terms ~ C_R	R3
S4	L_F | USER: □	~ Response ~ C_R	R4
S5	L_F | □~System Response ~ | C_R L_F		
S6	□~ System Message ~		

L_F Indicates Line Feed Character
□ " Space Character
~ " Variable Character String
C_R " Carriage Return Character
L_F is at times succeeded by a Null Character

Table 2. Stimulus and Response Format Modules

A frequently occurring module sequence transmitted by AIM-TWX is S1-S2-S4, where the format module S2 represents the start of the systems's request for a new Search Statement ("SS"). After the stimulation software has successfully detected this module sequence, it turns its attention to scanning the user's response for one of the eligible response format modules.

The stimulus and response format modules displayed in Table 2 are embedded in a number of different possible module sequences, including those displayed in Table 3. The terminology is purposely consistent with the S-R-S patterns discussed in Section 2.6. Thus, for example, a system stimulus may be a message beginning with S1, followed by variable data, followed by S2, followed by additional variable data, and finally terminating with the prompt to the user, namely S4. The user can then respond with a standard command R1 or a search statement R3 (unlike R1, not enclosed in double quotes) or with an (operating) system-enabled command R2. One of these responses in turn precipitates a system reaction in the form of another stimulus. It is at this point that the transparent stimulation framework can either allow a legitimate system stimulus or replace it by an artificial one. In either case, the user may or may not be asked to indicate his resulting level of satisfaction.

SEQ. No.	S-R-S SEQUENCE
1	[S1-S2-S4] – [R(1 or 3)] – [S1 . . .] –
2	[S1-S2-S4] – [R2] – [S5] –
3	[S1-S6-S2-S4] – [R2] – [S5] –
4	[S1-S6-S2-S4] – [R(1 or 3)] – [S1 . . .] –
5	[S1-S3-S4] – [R4] – [S1 . . .] –

Table 3. Possible Format Module Sequences

4.3 Screening and Matching Hierarchy

The number of possible module sequences (of those in Table 3) for which the intermediary system can actually scan naturally depends on the desirable sophistication and available capacity of the software and hardware facilities. For purposes of this project it was decided to restrict the implemented software to sequences numbered 1 and 2. However, all five were considered in initially prescribing a strategy for scanning user-system interchanges. This strategy is portrayed in the screening and matching hierarchy of Figure 3.

At the outset, the S1 module has to be sought in the character stream transmitted by the AIM-TWX system. As soon as a "hit" is registered, focus turns to finding S2. At this point, two major options can be made available. In case of S-2 miss, module sequences numbered 3, 4, and 5 (in Table 3) can be pursued; in case of S-2 hit, the next step in satisfying module sequences numbered 1 and 2 is taken. As already indicated, the latter option alone was found to be adequately complex to implement for purposes of this project. Software expandability to incorporate the other option, when and if feasible, is however provided.

The elements of Figure 3 are organized into clusters, labelled A through E, each of which displays a homogeneity in terms of module nature and/or length making it suitable for creation of a corresponding data file. These files are of course prerequisite to the process of scanning and matching the user-system message stream against the various predefined modules. Prior to the transparent stimulation procedure, the relatively short files are loaded into core, properly structured, to enable dynamic table look-up and consequent software-controlled decision-making on what action to take next.

5. PRESCRIPTION OF TESTABLE FEATURES

5.1 Characterization of Commands

In order to be able to test any hypothesis based on the assertion that certain human characteristics (see Section 2.5) are significant to the design of a user-system interface, it is essential to somehow characterize the available system features accordingly. Therefore, each of the AIM-TWX commands (or command types) was studied and consequently, using primarily subjective reasoning or intuition, categorized. The categorization criteria were:

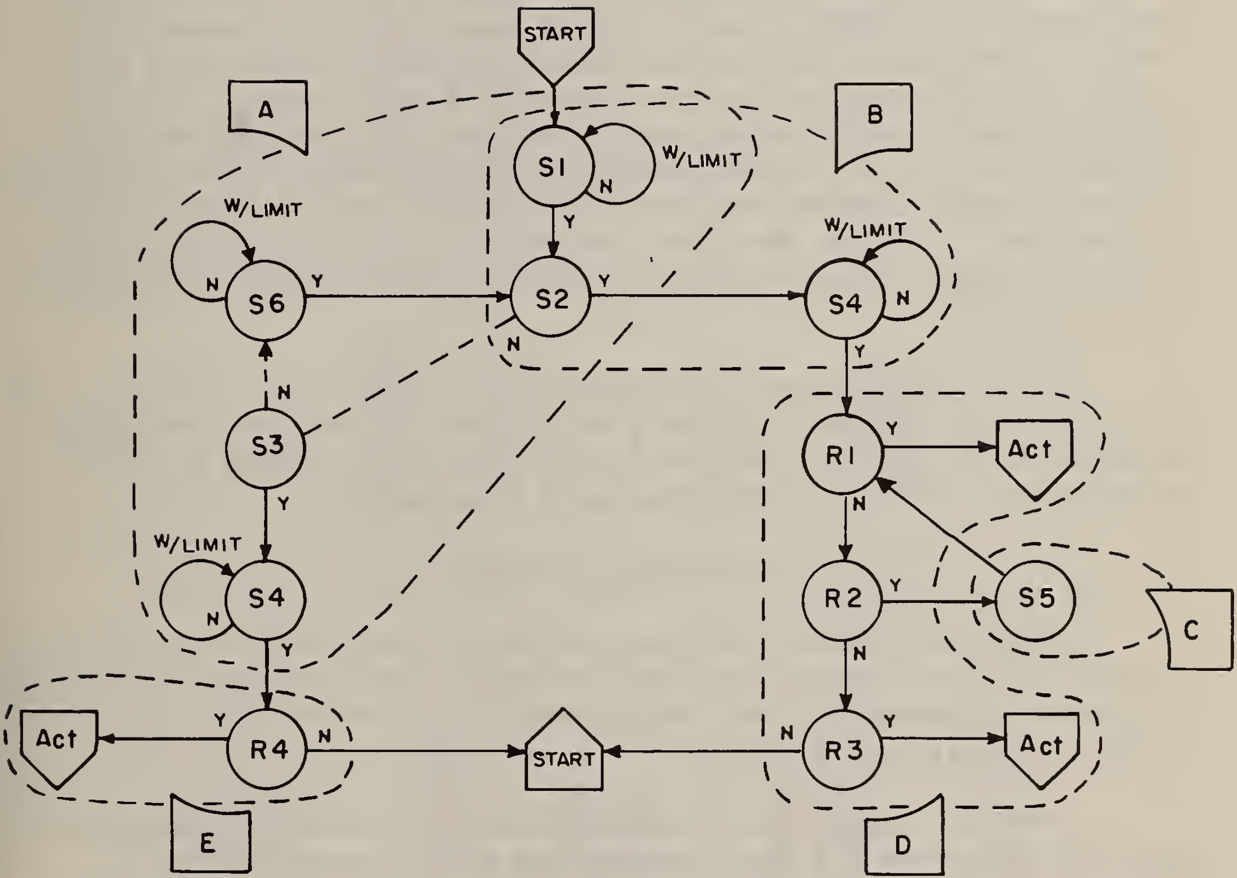


Figure 3. Hierarchical Strategy for Message Scanning

1. Primary or secondary applicability (if any) of a particular human characteristic to the command or command type.

2. Examinability (of the first criterion) at one or more of three levels of complexity.

Level of complexity refers to the degree of involvement of the intermediary (stimulation) system in the remote (AIM-TWX) system for purposes of studying a particular characteristic with respect to a specific command. The level is labelled "system-peripheral" if a characteristic can be studied independently of the features of the specific remote search system and without need for graphic manipulations. The level is "system-dependent" when remote system features have to become involved, but with no graphic interface manipulation as yet required. Thirdly, the most complex level is "file-dependent" in that both remote system functions and features and graphic manipulation become significant.

This categorization of commands is summarized in Table 4. The check mark (√) indicates primary and the dot (•) indicates secondary applicability of the identified characteristic to the command group (left-most column) at the corresponding level of complexity.

5.2 Selected Sub-Hypotheses

Due to the various time and equipment constraints on this project, it was decided to restrict the initial stimulation system design to the first two levels of complexity and, within those levels, to the characteristics which are underlined in Table 4.

How is it possible to hypothesize anything about the highly complex, serial nature of a user's interaction with a computer? This question is especially puzzling when there are confounding, cumulative effects to contend with, as far as a user's level of satisfaction is concerned. Nevertheless this transparent stimulation project is in part predicated on the belief that an honest attempt at developing a different approach and at resolving related difficulties is likely to be more beneficial to the man-computer interface than is not trying it at all.

A sequence of "sub-hypotheses" is defined relative to the categorization shown in Table 4. These are displayed in Table 5. The underlying rationale for each sub-hypothesis is:

Command	System-Peripheral		System-Dependent		File-Dependent	
COMMENT CMNT	✓	Responsiveness				
DIAGRAM... DIAG...			✓		•	Spatial Reference
ERASEALL ERSLL	•	Control	✓			
ERASEBAK... ERSBK	•	Reliability	✓			
EXPLAIN... EX... HELP... DESCRIBE...	✓	Support				
FIND... FD...			•	Accessibility	✓	Spatial Reference
MESHNO... MNO...	•	Reliability				
NEIGHBOR... NBR...			•	Accessibility	✓	Order, Association
NEWS	✓	Support				
ORDER...			✓		•	
PRINT PRINT TRIAL PRINT FULL	•	Control	✓	Completeness		
RENAME... RNM...			•	Simplicity		
RESTART RST	•	Control	•			
STOP	✓	Control				
TREE...			•	Accessibility	✓	Spatial Reference, Association
VERSION... VERS...			✓	Simplicity		
/ System Command	•	Reliability	✓			
~ Search Statement ~			•	Accessiblity	✓	

Table 4. Characterization of AIM-TWX Commands

TESTED CHARACTERISTIC	S-R-S MODULE SEQUENCE				Hypothesized USER REACTION
	System Stimulus	User Response	Related User Motivation	Artificial/Real Stimulus	
Accessibility	S1-S2-S4	FIND...	To Find Certain Items in the File	File is Busy, Must Wait	Negative
	"	NBR...	To See Adjacent Vocab. Entries	"	"
	"	TREE...	To See Related Vocab. Tree	"	"
Control	S1-S2-S4	ERSLL	To Erase All Search Statements	Sorry, Cannot Do That	"
	"	PRINT...	To Print More Than 2 Items	Only 2 Items Are Printed	"
	"	RST	To Restart Use From Scratch	Sorry, Cannot Do That	"
	"	STOP	To Quit Use of the System	"	"
Simplicity	S1-S2-S4	RNM...	To Rename Specified Command	Done as Requested	Positive
	"	VERS...	To Change Prog. Message Length	"	"
Support	S1-S2-S4	EX...	To Have Something Explained	Sorry, Explanation Not Available	Negative
	"	NEWS	To Get Current System News	Observer-Input "Live" News	"
Reliability	S1-S2-S4	ERSBK...	To Erase Certain Search Statements	Erases All Search Statements	"
	"	MNO...	To Get Specific MESH Number	Erroneous Number Is Printed	"
	"	/TIME	To Get Current Time of Day	Erroneous Time is Printed	"
	"	/USERS	To Get Current Number of Users	Erroneous (Small) No. is Printed	"
Responsiveness	S1-S2-S4	CMNT	To Input a Comment	Observer-Input Personal Response	Positive
	"	Any Command	Variable	Observer-Initiated Response Time Degradation	Negative

Table 5. Command-Specific Sub-Hypotheses

IF	WHEN	THEN
A CERTAIN HUMAN CHARACTERISTIC IS SIGNIFICANT TO INTERFACE DESIGN, IT IS EXPECTED THAT	THE SYSTEM GIVES POSITIVE/NEGATIVE REINFORCEMENT TO THAT CHARACTERISTIC (AFTER A USER RESPONSE)	THE USER SHOULD BE STIMULATED TO REACT POSITIVELY/ NEGATIVELY (OR FAVORABLY/ UNFAVORABLY)

It was previously stated that this project's focus is on studying user (not computer) behavior in user-system interaction, although the ultimate objective is of course to determine criteria for better interface design. Hence, in reference to Table 5, the above hypothesis format would assert, for example, that if the feeling of having "control" over the system is important to the user, he would be expected to react negatively whenever he asks to have five citations (known to be available) to be printed out and only two are actually printed.

Most of the AIM-TWX commands listed in Table 5 are abbreviated for convenience. The system scans for either full or abbreviated forms. The nature of each artificial stimulus generated by the intermediary system (at times with observer help) is necessarily only briefly indicated. Whether or not a user's reaction to such a stimulus is positive or negative (or indifferent) has to be ascertained by means of the specially designed on-line indicator device described in Section 3.3. Many of the sub-hypotheses portrayed in Table 5 may appear to be either trivial or self-evident. However, it is not clear that this is necessarily true or that it should preclude their experimental confirmation within the framework outlined.

6. EXPERIMENTAL PROCEDURE

6.1 User and Observer Environment

A special user terminal room, isolated from unwanted outside interference, provides the user with privacy and also makes him feel reasonably comfortable. As previously indicated, the terminal equipment available to the user is a Teletype, Model 33 (because an appropriate CRT was initially not available) and also the specially constructed "satisfaction level" device.

In addition, an intercom device is installed to enable the user to request immediate assistance, whenever essential, from the observer who is monitoring the user room by means of an intercom headset.

A compact clustering of AIM-TWX instructions and their brief descriptions is posted above the teletype in easy view of the user. The experimental user, who is selected based on having had previous experience with on-line retrieval systems, is expected to be able to review the posted instruction repertoire and without much difficulty become familiar enough to use it.

This task is further simplified by posting, on one side of the user-system interface, a detailed work assignment. It includes not only the exact sequence of steps to be carried out, but also the identity of each instruction to be employed. The added benefit of requiring such an interactive work sequence explicitly is the control it imposes on an experimental session for purposes of later comparison of experimental subjects.

To complete the list of items made available to the user, a copy of the MeSH Manual (Medical Subject Headings) is in his vicinity for reference or perusal whenever necessary.

The intermediary observer is located in a separate area, the computer room itself, and is faced with the very interesting and challenging task of monitoring/manipulating the user-system interaction by means of controlling all of the following devices in parallel:

1. Teletype Model 35 (Device 3 in Figure 2)

2. O-set (Device 4)

3. Teletype Model 33 (Device 5)

4. Communications Controller, for manual rerouting of messages or message components via different interfaces whenever the situation warrants

5. The Computer System, control console itself, for recovery from various error conditions whenever necessary

6. Intercom headset, for monitoring the user room and giving advice when essential.

6.2 Procedural Guidelines

As evidenced by the above list of devices he must control, the observer has a variety of activities to monitor and attend to. To aid him in doing so and in preparing and assisting and debriefing the experimental subjects, he is provided with a written set of guidelines to be referenced before, during and after each session.

6.3 Plans for Data Analysis

The collection of a number of different types of experimental data was initially planned. These included the following:

1. User and system response and processing time data, as collectable by means of the previously described Dialogue Monitor

2. Minimum response time variation data, using a special feature controllable by the observer

3. Observer-prompt to user response times (via special indicator devices) as tagged and printed out on the observer terminal (Device 3)

4. Satisfaction/reason indicator data, as collected on-line via the special user device following deliberate stimulation

5. Post-experimental questionnaire data, using a prepared questionnaire

6. Less precise but nevertheless invaluable record of experiences gained by the human observer in the performance of his role

The first of the above turned out to be infeasible because of the added complexities resulting from trying to run the Dialog Monitor in conjunction with the Transparent Stimulation Network. The second type of data, involving variation of minimum response time, is collectable using current software but is dependent on a basically different experimental design. The length of the project period precluded the testing of more than one design.

The remaining four types of data are applicable to the experiment that was carried out. As confirmed by Figure 4, the on-line satisfaction/reason indicator data are at the core of anticipated data analysis. The user can either be given a primarily positive (P) treatment or a primarily negative (N) treatment (see Table 5), depending on which interaction mode he is in. Hence, assuming the possibility of random assignment of experimental subjects to one of two groups, one gets treatments in P - N order and the other in reverse. It was planned that the tallying of individual user indications into individual and group matrices, such as portrayed in Figure 4, should enable certain kinds of

1. Inter-group comparison
2. Intra-group comparison
3. Inter-treatment comparison
4. Intra-individual comparison
   (vs. data collected via questionnaire)

and could result in implications on the significance of hypothesized human characteristics.

Perhaps the above sounds both questionable and presumptuous. However, recognizing the well-known difficulties in experimental control and design of such a complex and confounding process as man-computer interaction, it is nevertheless felt that some useful patterns, maybe only trivial or possibly unexpected, could result.

7. CONCLUSIONS AND RECOMMENDATIONS

A total of ten pilot test sessions, involving five different test subjects, have been conducted using the transparent stimulation network. In the process, a number of both major and minor improvements were made, ranging from significant smoothing of at times intolerably sporadic print-out (on the user terminal) to adding a more noticeable light on the special user device.

But three important problem areas remain. These cannot be alleviated without major changes in procedure or computer hardware or software:

Treatments →		P							N						
Reasons →		1	2	3	4	5	6	7	1	2	3	4	5	6	7
	1														
	2														
	3														
Emotions	4														
	5														
	6														
	7														

Figure 4. Overview of Plan for Data Analysis

1. Task complexity - Three of the five test users found that the user-system interface (including posted instructions) was initially "overwhelming." This may be attributable, at least in large part, to the fact that the test subjects who were conveniently available did not meet the stipulated prerequisite of experience with on-line retrieval systems although they have extensive experience with on-line systems in general. If this explanation is not born out in further experimentation with appropriately experienced users, then significant preparatory training as well as restructuring of interface posters may be necessary.

2. System transparency - From the user's point of view there are at times abnormal delays between print-out of one message segment (or line) and the next. This kind of delay cannot only become an irritation, perhaps overshadowing other system characteristics of concern, but it also detracts from the transparency espoused for the stimulation network. The basic reason for such delays lies in the fact that the message-store-scan-and-forward mode necessitates "handshaking" in the dual processor while accomplishing the task of message processing and forwarding simultaneously to further message receipt (in case of long messages). A thorough timing analysis of the dual processor system software could undoubtedly lead to minimization, if not total elimination, of this problem.

3. System reliability - Again, from the user's point of view, the system appeared to be unreliable too often. This was in part explained by memory parity and other such problems perturbing the particular computer system (especially during humid summer weather). But this was also regrettably due to a pure capacity problem. Thus certain user-issued commands, resulting in excessively long messages coming from the system, could literally flood (and crash) the system. Within its hardware and software constraints, the system could simply not process characters quickly enough to continually free up storage for newly incoming characters. Although a software safeguard against crashing the system

is clearly possible, the complete problem will undoubtedly not be overcome without complete rewriting of the applications software (perhaps at assembly language level) for a different computer configuration.

This project has provided valuable experience on how such a transparent stimulation framework can be designed and implemented. It seems clear that the above-indicated problem areas can be overcome. Although the task-specific experiment has only been pilot tested so far, the experimental procedure as outlined appears to be a reasonable first approximation. Perhaps an attempt should be made to minimize the nonintellectual aspects (e.g. routine button control) in the role of the unobtrusive observer. His job was found to be quite challenging.

The general stimulation framework as developed and described herein holds considerable potential for research into various characteristics of the man-computer interface. This conclusion precipitates the following recommendations:

1. In general, experimentation within the environment afforded by such a stimulation framework should continue.

2. More specifically,

    a. The stimulation support software should be reprogrammed for a more modern research computer configuration with above-indicated problems eliminated. Graphic terminals should replace teletypewriters. New research computer equipment has recently been acquired to augment CCST research facilities and plans are being formulated for further work of this type utilizing these facilities.

    b. A complete experiment, still oriented to the task of on-line retrieval, should be carried out. This should of course be followed by interpretive analysis of the experimental data.

    c. Depending on the success of that experiment, either further experiments similar in nature may follow, or further study to modularize the stimulation framework for also handling other types of interactive applications (e.g. CAD&E, CAI) might be in order.

3. Lastly, various features of the stimulation framework, such as on-line collection of user preference data via special-purpose devices, should be regarded and reviewed as potentially applicable to the CCST Dialogue Monitor project, in particular, and to the entire CCST teleprocessing performance measurement area, on the whole.

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A computer terminal network to enable "transparent stimulation" of the user of an on-line retrieval system has been designed, implemented, and pilot tested. Its basic purpose is to provide a suitable and effective framework and methodology for experimental identification/validation of those human characteristics which should be recognized/reinforced in man-computer interface design. The rationale behind the transparent stimulation approach is presented and the methodology employed for such real-time, unobtrusive scanning and manipulation of the man-computer dialogue is described. A general overview of the hardware and software features of the implemented stimulation network is included.

17. KEY WORDS (Alphabetical order, separated by semicolons) Computer terminal network; human characteristics; interactive information retrieval; man-computer interface; transparent stimulation; unobtrusive monitoring.

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