NBSIR 73-289

# Characterization and Testing of Interactive Graphics for Computer-Aided Design and Engineering

Siegfried Treu

Computer Systems Section
Institute for Computer Sciences and Technology
National Bureau of Standards
Washington, D. C. 20234

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Interim Report for Period July 1972 to June 1973

Prepared for
**Contract No. 73-90042**
**U. S. Army Electronics Command**
**Fort Monmouth, New Jersey 07703**

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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CONTENTS

# 1. INTRODUCTION

## 1.1 Background

The material presented in this report is based upon studies conducted over the period of 1 July 1972 to 30 June 1973 as part of a long-term "Interactive Computer-Aided Techniques Study" initiated in August 1970. This long-term effort of research, development and consultation by the National Bureau of Standards is in direct support of the AMC program for the implementation and promotion of the techniques of computer-aided design and engineering (CAD/E).

The intent of this cooperative program between NBS and the Graphical Systems and Technology Branch of the Electronics Command (ECOM), under AMC, is to provide both general and specific assistance to ECOM in the initiation and use of interactive graphics as a new and important tool in CAD/E.

## 1.2 Project Scope

ECOM has undertaken the development of a prototype system for the support of CAD/E. The concept of this design terminal has been termed MEDEA--Multidiscipline Engineering Design, Evaluation and Analysis. The basic goals of the MEDEA system have been described as follows[1]:

1. Put the man in the computer loop as a problem solver not as computer specialist.
2. Provide an interactive rate compatible either with the scientist/engineer/designer process function or with the user's problem solving rate.
3. Provide simple and unified access and use of analysis, evaluation and design procedures and data for many technical disciplines.

4. Provide interactive, conversational use with interactive graphics as the principal input/output medium.
5. Provide for the accumulation of and cross-referenced access to user designated abstracts of use of the computer-aided system.

The role of NBS has been to review the design considerations for the MEDEA system, taking into account the design constraints, the capabilities of local versus remote processors for the support of CAD/E, and the trade-offs between hardware and software implementation of graphics functions. A specific task for NBS has been to make recommendations regarding the evaluation of graphics systems for CAD/E and to formulate a program for measuring the performance of the MEDEA system with respect to the stated design objectives.

This report deals specifically with techniques for evaluating the efficiency and effectiveness of graphics systems for CAD/E, and the assessment of user satisfaction. A discussion of the economic aspects is presented in a separate document.

## 1.3 Related Activities

A subordinate role for NBS has been to provide ECOM with the means of obtaining access to the facilities of the ARPA (Advanced Research Projects Agency) Network. The ARPA Network, in turn, provides access to a wide variety of computer systems, many of which are capable of supporting CAD/E, either in a batch mode or interactively. NBS has been established as a node on the ARPA Network and has a TIP (Terminal Interface Message Processor) with a PDP-11 host processor. A communications protocol for use by ECOM in accessing the ARPA Network was developed earlier and has been described in a previous report[2].

## 1.4 Overview

This report outlines the stages of development in the utilization of interactive graphics as a tool for CAD/E. It presents a series of characteristics which are of significance to the designers and users of such systems and poses a series of questions of evaluative interest, which are intended to delineate the extent to which a system under examination achieves its stated design objectives. These characteristics are grouped in accordance with the nature and complexity of the experiments which would need to be conducted to establish values for them. The report then proceeds to select specific characteristics of particular interest and suggests the design of experiments for examining these characteristics in detail. As the MEDEA system evolves to a fully operational status, the techniques outlined in this report can be applied to assess the degree of user satisfaction achieved and to suggest lines along which further development may be pursued.

## 2. CHARACTERISTICS OF THE INTERACTIVE DESIGNER

### 2.1 Motivation

The performance of interactive graphics systems can be tested and evaluated in a variety of ways, ranging from very selective and objective consideration of specific hardware/software functionings to a very comprehensive and (in part) subjective assessment of the man-computer relationships involved. A methodology exemplary of the latter is the previously reported Symbiosis-Efficiency-Effectiveness (SEE) approach[3].

To develop an appropriate methodology and meaningful measures, a characterization of the interactive graphics system is essential. If it is viewed to be only an embodiment of graphics hardware and software for enabling interactive design, independent of the man-computer interface questions involved, then the technical specifications and performance of the system can be analyzed in a purely objective manner without the considerable complications arising from human user experiences and judgments. If, however, the designer is considered to be an important and integral part of a man-computer team, the difficult concerns about human user characteristics must be confronted[4].

Dunn has recently stated[5] that

> ...useful measures for interactive graphics systems are dependent upon subjective judgments [which] are made by both the users of the graphics consoles and the operators and owners of the supporting systems. Hard-to-measure, non-analytic factors, such as, "effectiveness," "productivity", "usefulness", and "satisfaction" are subjects

of these judgments. After all is considered, the reason for interactive graphics is the human-in-the-loop.

As confirmed by the contents of this report, the "human-in-the loop" requirement has been the focus of a considerable segment of our work during the past year. It was not carried out to the exclusion of concern about the characteristics and capabilities of the hardware/software facility (MEDEA) itself, but rather with the intention of creating testable hypotheses on the performance of the designer-system partnership.

We cannot meaningfully test a man-machine relationship unless we have some specific criteria or factors which are deemed to have some significant bearing on good/bad performance. For example, the determination of "responsiveness" of a system would be useless without clear indications that response time happens to be an important feature[6,7] which human users observe and which appears to have various interesting effects[8]. But that is not the only feature or characteristic which is of significance to humans. This section is devoted to development and description of a more complete profile of characteristics which are (or can be) hypothesized to be important to the human designer who is attempting to take advantage of an interactive graphics system such as MEDEA.

## 2.2 Stages of Graphical Interaction

Katter and McCarn have published[9] an interesting description of the reactions of interactive users of on-line retrieval systems. They characterized three roughly sequential phases in the development of user-system interaction. These can be briefly summarized as follows:

Phase 1. Confidence: The user shifts from an uncertain and hesitant approach to a more relaxed attitude of ease and optimism about his ability to cope with the system.

Phase 2. Insight: The user shifts from the somewhat unquestioning rote memorization and practice (in Phase 1) to learning about more general underlying principles and potentials of the system.

Phase 3. Incorporation: The user shifts from regarding the system as novel and supplementary (to his own resources/methods) to incorporating its capabilities as an essential element in his pertinent information seeking/using pattern.

Such phases are not peculiar to users of on-line retrieval systems. Similar phases or stages undoubtedly exist in the progression of steps taken by a novice towards becoming an experienced designer utilizing interactive graphics. A suggested sequence is portrayed in Figure 1.

First, the uninitiated designer must learn the fundamentals. At this stage, he may feel overwhelmed by procedural details and by having to remember simple but necessary instructions pertaining to such things as cursor (re)location and light pen operation. The learner may require considerable personal (or on-line) assistance, and, in order to develop self-confidence, he needs the reassurance which comes from repeated successful experiences and observations that personal errors do not cause system disasters.

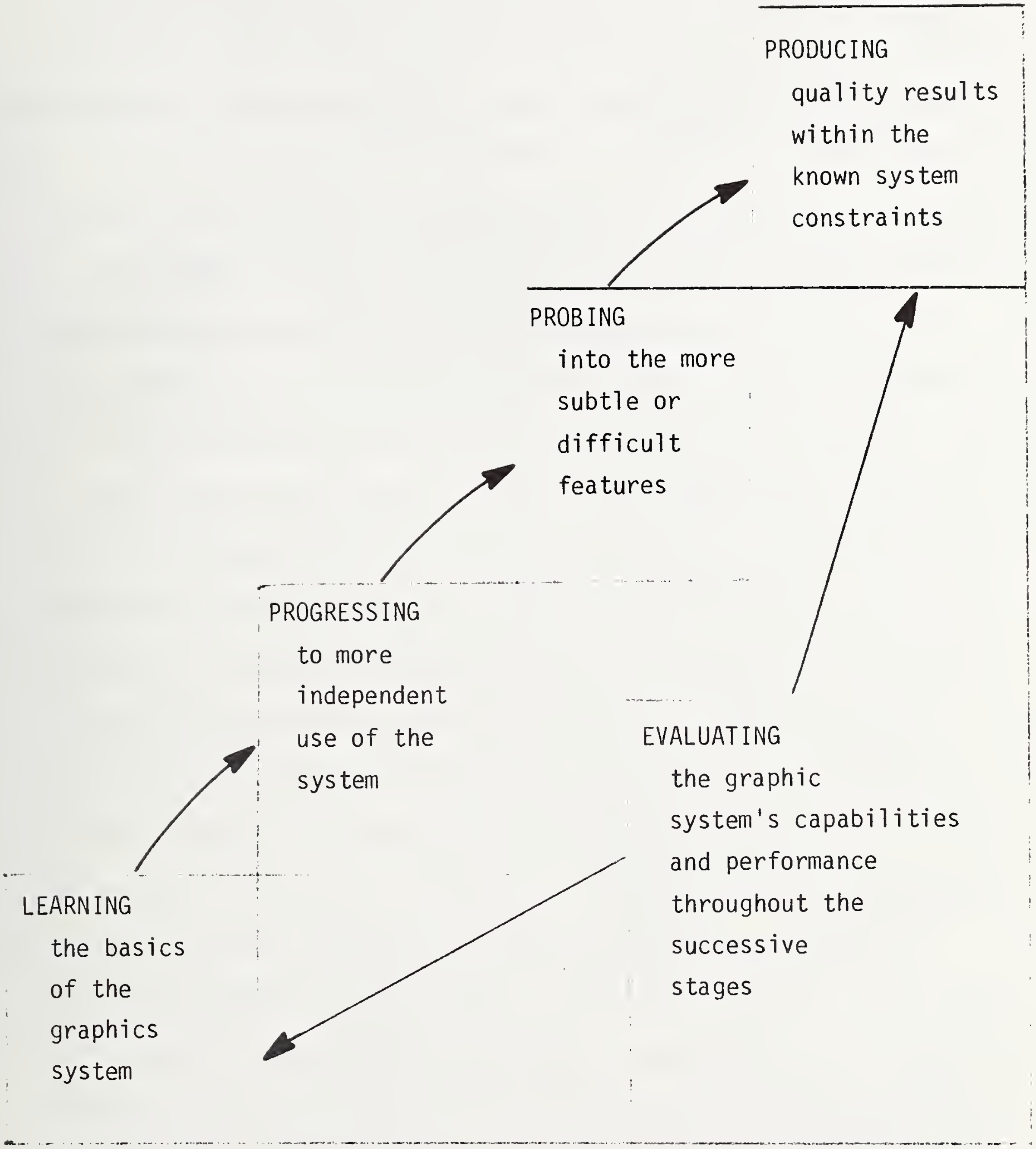


Figure 1. Interaction Stages

After overcoming at least most of the hurdles confronted during the learning stage, the interactive designer should then find himself progressing to more independent status. Experience now has demonstrated to him that he can remember and carry out the simple procedures and operations in comparatively routine fashion, and hence he can start to pay more attention to the interactive design objectives themselves.

In so doing, and as he finds himself attempting more complicated and advanced designs, he quite naturally moves to the next stage, namely the probing. At this point, curiosity and initiative urge the designer towards determining perhaps hidden system capabilities which were neither apparent nor required during the more superficial early stages. Here he might ascertain, for example, that some helpful perspective views are possible through certain versatile manipulations of the graphic objects on the display screen. On the other hand, he may find out that the system is strictly limited in some respects, such as in the precision obtainable from calculations returned from supporting analysis software.

Having gained a reasonable level of experience with the graphics system and a realistic assessment of what it can or cannot do for him, the user can now settle down to a kind of "steady-state" phase in which he performs various design tasks in an operational mode. He may have resigned himself to living within the existing system constraints and, in that context, taking advantage of the available graphics facility to its fullest. While he may still need to learn more about it and to progress further as an interactive designer, and while he may at times continue to probe into accomplishing the tasks more effectively and efficiently, he can nevertheless be considered a relatively experienced designer who is able to produce on a regular and reliable basis.

As is also indicated in Figure 1, the designer can naturally be expected to observe and evaluate the graphics system performance throughout the learning, progressing, probing and producing stages. This happens to be quite important because we want the human-in-the-loop to be ready and able to make evaluative judgments (see Section 2.1). But, in order to gather such data in a consistent and potentially useful manner, a common basis for the selection and grouping of designers according to levels of experience is highly desirable. The main purpose of this section, therefore, has been to develop a rationale for distinguishing the backgrounds of persons who may become available for experimental (operational) testing of the MEDEA graphics facility. Depending on whether a designer is at the learning, progressing, probing, or producing stage, his behavior, expectations, requirements and evaluative opinions may be quite different and should be interpreted accordingly.

## 2.3 Questions of Evaluative Interest

A specific question about the performance of a system can be viewed as a criterion for system evaluation. If, for example, an interested party wants to have an answer to the following question:

Is the MEDEA response time good enough to satisfy designer expectations?

then, assuming we know (or find out) what the designer expectations are and how many of the local designers are to be satisfied, a "yes" or "no" (qualified by %) should at least be possible. This answer can then be regarded as one among numerous other possible factors carrying evaluative information about good/bad MEDEA performance.

But, instead of attempting to compile an exhaustive list of evaluative questions that could be asked about the MEDEA facility, it is more manageable to identify a set of pertinent and desirable characteristics which would be inferred collectively. The above-asked question clearly implies that "responsiveness" is an important system characteristic. Other questions, appropriately grouped, would similarly suggest other features or characteristics which, taken in their adjectival form, are not only descriptive and useful but also subject to experimental validation. The next subsection provides their definitions.

## 2.4 Definitions of Desirable Features

In the published paper[10] entitled "A Conceptual Framework for the Searcher-System Interface", a portrayal of the system characteristics desirable from the human user's standpoint was made. It was asserted that these must be taken into account in designing the man-computer interface for purposes of on-line information retrieval.

A similar characterization, appropriately re-oriented to graphics-aided design, has been carried out in preparation for testing the MEDEA system. It seems only reasonable that, to develop useful experiments and related measurements for evaluating/demonstrating the performance of that system, we should first have an understanding of what features or characteristics appear (or are hypothesized) to be good/bad or advantageous/disadvantageous for the human designer wanting to employ a graphics system for computer-aided design.

Following is a suggested list of such characteristics. They are identified in alphabetical order but their respective definitions are not given in dictionary style. Instead, because the general meaning of each characteristic is commonly known, one selected question of evaluative interest (along with some brief commentary) is used to indicate the specialized meaning of each term.

| CHARACTERISTIC | INDICATIVE QUESTION OF EVALUATIVE INTEREST |
|---|---|
| 1. Accessibility | Can the designer gain access to (i.e. use) the graphics system hardware/ software when necessary/desirable? If you can't get at the system (on some schedule), you obviously can't get your design task accomplished. |
| 2. Accuracy | Are the computations as well as graphic positionings accurate? The results of graphics-aided design become understandably suspect if numeric/positional errors (beyond some margin) are detected. |
| 3. Association | Can objects and/or design parameters be associated both explicitly (by graphic |

connection) and implicitly (by proximity)? The human mind quite naturally establishes such association links. Graphics should facilitate them.

4. Compatibility

Are the graphic display features (e.g. screen size, character size, color, etc.) and performance (e.g. interaction rate, flickering) compatible with human capability? For better man-machine performance, the graphics machine should be tailored to be conducive to and capitalize on man's capabilities.

5. Completeness

Does the repertoire of available graphic manipulations include the normally expected move, rotate, zoom, erase, etc.? If the graphics facility is incomplete or comparatively primitive in the operations enabled, much of its attraction is lost.

6. Continuity

In moving/manipulating the displayed graphic objects, is the sequence of system actions non-sporadic? Highly irregular or unpredictably spaced motions or actions on the screen become disturbing.

| | |
|---|---|
| 7. Control | Does the designer maintain control over the design process (e.g. can he interrupt it)? Having no recourse but to helplessly wait for the system to do its thing is both unproductive and undesirable. |
| 8. Flexibility | Can the graphic objects (including characters) be modified in size and shape? Dimensional restrictions preclude many of the more interesting and useful effects which interactive graphics should provide. |
| 9. Mobility | Does the designer have enough freedom to move the graphics objects on the screen? If the display area itself, the available operations, or the interactive tools (e.g. light pen) make movement cumbersome or restrictive, the graphic environment is comparatively static. |
| 10. Order | Are the command menu, the graphic symbols menu, etc., displayed/ displayable in meaningful arrangements? The human mind tends to find things |

more easily when knowingly and sensibly ordered (e.g. alphabetically).

11. Power

Does the graphics system have enough capacity and capability to handle complex designs? If it can only be used for very simple designs, its value to the sophisticated designer will become marginal.

12. Reliability

Is the graphic system reliable in operation? If not, the designer's confidence and interest in the system will diminish.

13. Responsiveness

Is the response time good enough to satisfy designer expectations? To close the man-machine communication gap, the machine must be rendered (appropriately) responsive.

14. Simplicity

Are the interactive language and procedures simple enough to enable easy learning? If the steps towards becoming reasonably proficient are too unwieldy and require too much memorization, the average designer will not be served well.

15. Spatial Reference — Does the designer's sense of spatial reference get adequate reinforcement on the graphics screen? That is, afterall, one of the important justifications for graphics.

16. Support — Can the designer request and get (on-line) help when he needs it? When puzzled about what action to take next, some effective/friendly form of assistance goes a long way towards making the user more at ease.

17. Versatility — Is the graphics system versatile in enabling different types of design, different I/O devices, etc.? If you prefer and are used to a light pen, you should not be forced to use a joy-stick or some other means.

Depending on precise interpretation of the above-listed characteristics, others could undoubtedly be added. Furthermore, interrelationships obviously exist. For example, a system cannot be adequately responsive if it lacks the required power. It is also clearly impossible to achieve the espoused flexibility and versatility unless a minimally complete repertoire of graphic manipulations is available. Nevertheless, each of the characteristics is important enough to warrant separate recognition.

Since our objective is to prepare for the testing of the MEDEA system with respect to (at least) some of these characteristics, we should attempt to relate them to the interaction stages described in Subsection 2.2. Does the beginning interactive designer (Stage 1) perhaps view one or more of the suggested characteristics differently than when he reaches a later stage (e.g. Stage 4)? Table 1 portrays possible ranges of major applicability. As is true for the characteristics themselves, the indicated ranges await empirical verification.

## 2.5 Emphasis on Symbiosis

As stated in Subsection 2.1 and as confirmed by the list of desirable features identified in the previous subsection, the main thrust of this report is on the symbiotic relationship which may or may not exist between the designer and his graphics system. All of the characteristics, from accessibility to versatility, have one thing in common: If representative evaluative questions must be answered in the negative, then the human user is somehow detrimentally affected. Either he is consequently less satisfied and hence (perhaps) less inclined to work well, or he may be performing below his capabilities unknowingly due to certain system incompatibilities or failures which do but need not exist.

The importance of the symbiosis aspect should therefore be clear. Even though it represents only one of the three major aspects of the SEE approach[3] and even though it has more often than not been ignored or conveniently set aside as too difficult to handle, symbiosis should actually be of priority concern. Not only does it have obvious bearing on the human-in-the-loop, but it also exerts substantial influence on system efficiency and effectiveness.

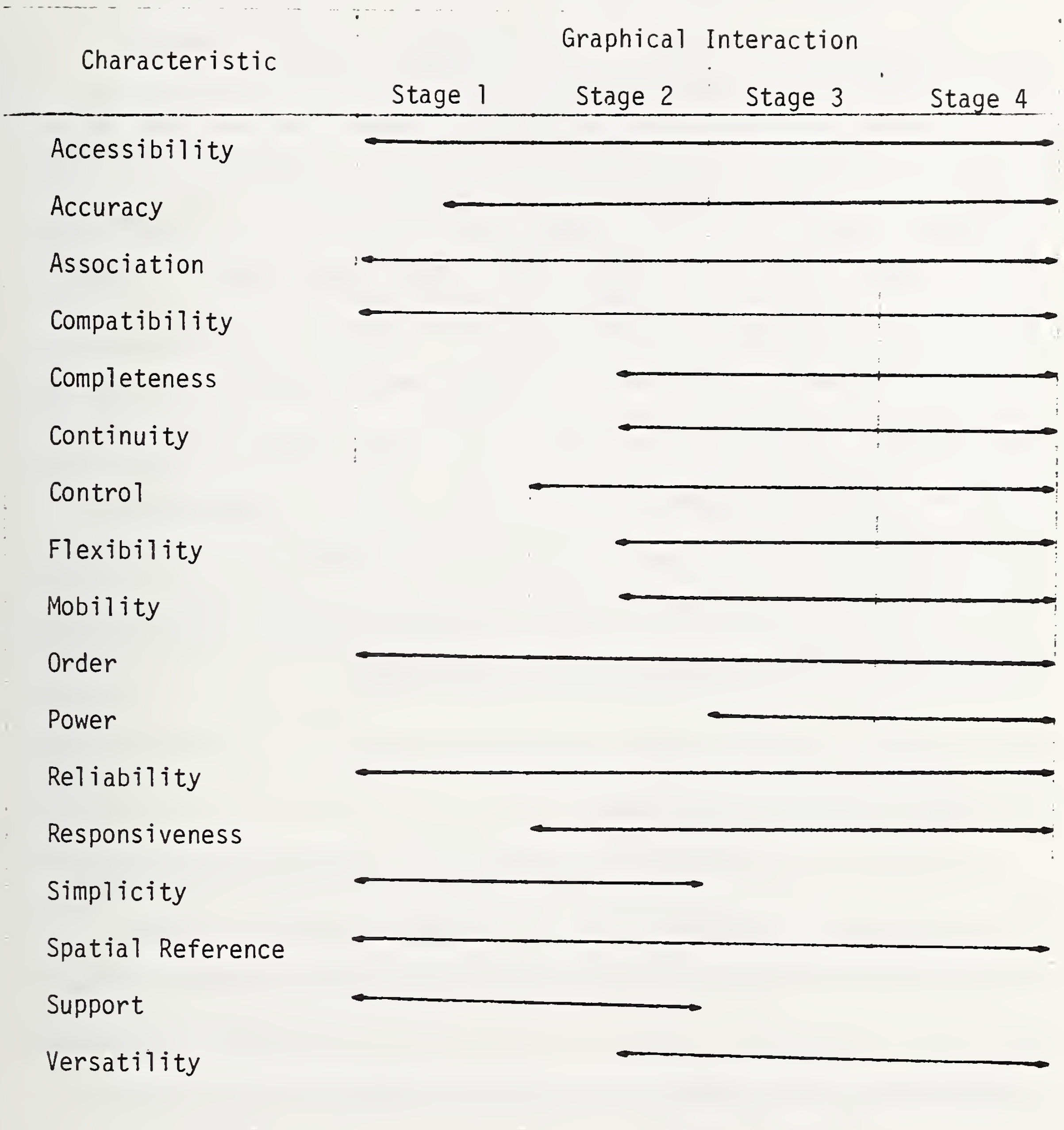


Table 1. Ranges of Major Applicability

## 2.6 Efficiency and Effectiveness

Just because the graphics system exhibits a certain symbiotic characteristic, does that necessarily make it any more efficient or effective? In some cases, especially reliability, one would certainly expect so. In others, such as mobility and versatility, it is not as clear. Expenditures for too much power and too many other nice capabilities can conceivably become luxurious in nature, particularly if the users and their normal work assignments do not require such features. Consequently, cost effectiveness may not be demonstrable for certain profiles of graphic system characteristics. But the complex interrelationships existing between user satisfaction and motivation and productivity, etc., must first be more thoroughly studied, tested, and analyzed before reaching any general conclusions.

# 3. EXPERIMENTS FOR THE MEDEA SYSTEM

## 3.1 Data Collection Requirements

A list of characteristics asserted to be of significance to the designer-system interface has been presented in Section 2. After studying each of these very closely and after pinpointing the related questions of evaluative interest, we can more easily determine what data (and measures which meaningfully transform those data) are required to arrive at evaluative answers.

Identification of the required data, in turn, enables a prescription of what software and hardware mechanisms should be implemented to collect/measure those data. After such implementation and data collection, the data analysis and methodology for reaching evaluative conclusions, about

MEDEA will depend on whether the decision-oriented or threshold-oriented approach is taken[3].

The above-indicated procedure for deciding on required data and data collection techniques should be carried out with respect to each individual characteristic under consideration. For example, if reliability is to be determined, we must ask what is necessary to find out whether MEDEA is reliable. A similar question must be asked for any other characteristic to be specifically studied. To preclude the possibility of duplicated or redundant implementation/instrumentation efforts, the data collection requirements can then be pooled for all the characteristics to be tested.

Simplicity and responsiveness are being recommended as appropriate characteristics to be sought in the MEDEA system. Their selection will be justified in the next subsection and respective experimentation is described in Subsection 3.3 A system is implied to be "simple" if its users are observed to require only short time periods for system-related thinking, to issue infrequent requests for help, and to have learned relatively little specialized technical information. A "responsive" system, on the other hand, reacts to a user command after a time interval which is compatible with the user-required delays for thinking and psychological adjustment.

1. To ascertain whether MEDEA exhibits simplicity, required data include:

   a. A record of the actual interaction sequence or dialogue involved.

   b. A record of the "think times" as well as total times expended in various phases of the design process.

c. A record of requests for assistance made by the designer.

d. A record of design opinions expressed during or after a design session.

e. Any data to substantiate how much the designer had to learn in order to use MEDEA effectively.

To collect these data, the following tools/techniques are called for:

a. An on-line graphics dialogue monitor and recorder.

b. Time tagging of all messages (or graphic display manipulations)

c. An on-line opinion gathering mechanism.

d. A post-session questionnaire.

e. A special-purpose designer learning experiment (described in Subsection 3.3).

2. To find out whether MEDEA exhibits <u>responsiveness</u>, required data include:

a. A record of all response times.

b. A record of the interaction sequence to determine individual design subtask completion.

c. A record of expressed designer opinions on response times.

d. Any data to indicate just how often the designer waits for a late system response or is unprepared to react to an early system response.

To collect these data, essentially, the same types of data collection tools/techniques are needed as for studying simplicity (see above). However, a different special-purpose experiment is suitable (described in Subsection 3.3).

## 3.2 Levels of Experimental Complexity

Although there may be various similarities among data collection tools and techniques employable in testing for the previously described system characteristics, that is not to say that the experimental complexity is about the same. In fact, depending on the type of characteristic and the nature of the data collection sources available and applicable to it, the level of complexity in experimentation may vary considerably.

A characterization of these differences is shown in Table 2. It is intended to emphasize the existing spectrum of data collection sources, ranging from highly objective and easily obtainable system records and logs to the very complex psychological/physiological explanations of man's interaction with a machine. The latter are obviously not as easily dealt with and even understood. The categorization (in Table 2) of the characteristics according to complexity levels is not asserted to be definite or final. It merely represents current intuition-based interpretation of the meaning of each term and consequent expectation of the difficulty in experimenting with/for it.

As previously stated, "responsiveness" and "simplicity" have been selected for initial attempts at pertinent experimentation. According to Table 2, these characteristics are considered to be at levels 2 and 3 respectively. Hence they should be representative of the more interesting and challenging characteristics to test for. Furthermore, because both of them will require the availability of suitable experimental subjects (i.e. human designers), the latter should be at appropriate stages of graphical interaction (see Table 1).

| LEVEL | NATURE OF DATA COLLECTION SOURCES | APPLICABLE CHARACTERISTICS |
|---|---|---|
| 1 | Available records, logs, technical descriptions, direct observations | accessibility<br>accuracy<br>completeness<br>flexibility<br>reliability<br>versatility |
| 2 | In addition to the above: Subjective designer judgments and opinions | continuity<br>control<br>mobility<br>power<br>responsiveness<br>support |
| 3 | In addition to the above: More complex psychological and physiological considerations | association<br>compatibility<br>order<br>simplicity<br>spatial references |

Table 2. Levels of Experimental Complexity

The simplicity (or learnability) characteristic seems to be especially important during early stages. Hence related experimentation will be possible with the group of designers who will first be getting access to and learning about the MEDEA facility as it becomes operationally available. Responsiveness, on the other hand, appears to be a popular and logical follow-on in that it becomes more prominent beyond the learning stage. Thus, perhaps the same group of designers could be available for and willing to participate in both experiments.

Another important justification for the selection of simplicity and responsiveness experiments is indicated in the next subsection.

### 3.3 Description of Suggested Experiments

In previously provided documentation about ECOM's Design Terminal Concept and as recently restated by Gray[11], one of the design specifications is that

> ...the man that is put in the loop
> be a problem solver, not a computer
> specialist.

Among the performance objectives for the graphics terminal, Gray not only included ease of use but also an interaction rate commensurate with the user's activities.

These guidelines clearly lend themselves to corroboration of the simplicity and responsiveness experiments described below.

#### 3.3.1 Simplicity

To test and evaluate MEDEA with respect to this criterion, we should design an experiment which may ascertain how easily the usage of MEDEA can be learned. Does the human user have to become something of a computer specialist before he can really understand and operate the MEDEA system to advantage?

Hence, with regard to "simplicity," the following experiment is outlined:

1. OBJECTIVE: To determine how frequently and under what circumstances the designer requests/requires specific assistance and/or makes identifiable mistakes, and to observe the distributions of those numbers across n design sessions by each user. Secondly, to study how many "computer specialties" are learned by the uninitiated user between the start of session 1 and the finish of session n.

2. PREREQUISITES:
   a. Availability and selection of a suitable group of experimental subjects who are not experienced with MEDEA (or other interactive graphics systems).
   b. Identification of a design assignment, of representative complexity and reasonable duration, which each of the subjects could <u>learn to</u> carry out.
   c. Possibly the same kind of special keying mechanism required in conjunction with the responsiveness experiment (Subsection 3.3.2), to enable the user to indicate when assistance is required or when a subtask is difficult to understand or accomplish.

d. Clear identification of a manageable set of "computer specialties," or concepts/topics which a non-computer specialist is not expected to know about while a person with adequate experience in the area should.

e. Carefully prepared pre- and post-experimental questionnaires to probe into and distinguish how much the user knows about the selected "computer specialties" before and after the sequence of n interactive graphics sessions.

f. Scheduling for and planning the control over the experimental sessions.

3. INDICATOR DEVICE: User-indicated trouble spots requiring assistance can of course be verbally communicated to an available staff member. However, it would be preferable to supplement the verbal mode by a simple automatic logging procedure (which perhaps could also activate a buzzer/light to call for staff help). The keying device described in Subsection 3.3.2 could serve this purpose.

4. GENERAL PROCEDURE: Prior to a new user's first design session, he/she is properly briefed (including a minimal demonstration) and then asked to complete the pre-experimental questionnaire.

Then the user can proceed with the scheduled number of design sessions for purposes of accomplishing the assigned design task(s). Throughout these sessions, requests for assistance must be communicated (and keyed in) by the user and of course anticipated and recorded by available staff.

After the sequence of design sessions is finished the user is asked to complete the post-experimental questionnaire and also debriefed to gain any opinions about learning requirements or difficulties.

5. EXPECTED RESULTS: The data collected as described above and also by means of other tools (listed in Subsection 3.1), should enable analysis for determining at least the following:

a. (Individual and collective) distributions of the number of requests for assistance and the number of committed mistakes, from the first to the nth sessions.

b. Average % of learning (or some other measure) of the set of "computer specialties" over the period of design sessions.

c. Dependencies or relationships (if any) of the data considered in a. and b. with respect to other recorded user characteristics or experience.

d. Comparison of the real-time user learning performance with later user opinions (gathered by questionnaire).

e. Feasibility of this technique.

### 3.3.2 Responsiveness

The testing and evaluation of the ECOM graphics facility to determine, among other characteristics, its level of responsiveness, requires that we employ several different data collection tools. These were outlined in Subsection 3.1. To supplement the data on actual response times experienced etc., an appropriate, specially designed experiment is possible. It is outlined as follows:

1. OBJECTIVE: To determine how frequently and under what circumstances the designer is mentally prepared to tackle the next design step but is unable to do so because the graphics system (ECOM's MEDEA) has not yet responded. Secondarily, to consider the opposite problem of the response being at times too fast for the designer's rate of assimilation or preparation.

2. PREREQUISITES: a. Availability and selection of a suitable group of experimental subjects who have advanced beyond the beginner's stage and can give serious thought and attention to the overall interaction flow.

   b. Identification of a design assignment, of representative complexity and reasonable duration, which each of the subjects could carry out.

c. Design and implementation of the facility for enabling the designer to key in the desired response time indications and for having these properly time-tagged (along with the normal interaction sequence).

d. Scheduling for and planning the control over the experimental sessions.

3. VARIATION: It may be desirable not only to enable the designer to indicate "too slow" and "too fast" response time, but also (especially for the former case) to let him qualify the indication by distinguishing warranted from unwarranted delay. If the designer is knowledgeable enough to recognize that the subtask being executed warrants a longer response time, he should in effect be able to say: "I'm ready, but I realize that the system is working on a complex subtask."

4. INDICATOR DEVICE: If the objective as stated and as qualified above is to be accomplished, the keying in of user-indicated time spots must be enabled. Possible enabling devices include:

a. An autonomous little keyboard (such as the Keyset used by Doug Englebart's group at SRI[12]).

b. A grouping of (at least three) functions or other special buttons in the existing keyboard.

c. A grouping of (at least three) selectable dots displayed in some corner of the graphics screen.

In any case, the choice should make it as simple, non-confusing, and non-disrupting to the designer as is possible.

5. GENERAL PROCEDURE: Whenever the designer has completed his side of a transaction and is consciously sitting there and realizing that he is ready to undertake the next step, he should be able to simply push/select a special button to so indicate. An associated button could be available in case he recognizes that the delay is warranted.

Furthermore, if the response is perhaps faster than the user can handle it (e.g. possibly because of a need to reference some hard-copy tables at that point), a third (labelled) button could be pushed as soon as he is ready to assimilate the response.

6. EXPECTED RESULTS: If this experiment is properly carried out, we should be able to analyze the data and ascertain at least the following:

a. Average frequencies of excessive, appropriate, and unnecessarily fast response times.

b. Correlation (if any) of those frequencies with different types of design subtasks (and varying levels of complexity).

c. Comparison of the real-time user indications with later user opinions (gathered by questionnaire).

d. Feasibility of this technique.

## 4. CONCLUSIONS AND PLANS

A detailed characterization of the stages of graphical interaction and of the graphical terminal features which the human designer deems to be important has produced the groundwork, specifically oriented to the MEDEA system, on which experimental testing can now be based. The two suggested experiments concerned with simplicity and responsiveness reflect the progress made by ECOM towards bringing a symbiotically designed graphics facility to fruition.

We have reached a point at which we can focus on certain features and plan for testing MEDEA with respect to their presence/absence or level of performance. This means that the development of the design terminal concept has gone far enough to enable our specification or suggestion of those hardware/software devices or techniques which must be incorporated in order to support the experimentation desired.

As the multi-user operating system software for MEDEA is completed in the not too distant future, it will therefore become possible to realize the data collection tools in operation. Our plan is then to continue the interaction between the staff of ECOM and NBS, not only in terms of providing further guidelines for implementation/instrumentation but also by means of assistance in the various preparatory, control, data collection and analysis tasks involved in experimentation.

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FORM NBS-114A (1-71)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBSIR 73-289 | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|

| 4. TITLE AND SUBTITLE | |
|---|---|
| Characterization and Testing of Interactive Graphics for Computer-Aided Design and Engineering | 5. Publication Date: 30 June 1973 |
| | 6. Performing Organization Code |
| 7. AUTHOR(S): Siegfried Treu | 8. Performing Organization |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: NATIONAL BUREAU OF STANDARDS, DEPARTMENT OF COMMERCE, WASHINGTON, D.C. 20234 | 10. Project/Task/Work Unit No.: 6505373 |
| | 11. Contract/Grant No.: 72-90013 |
| 12. Sponsoring Organization Name and Address: U.S. Army Electronics Command, AMSEL-GG-OD, Ft. Monmouth, New Jersey 07703 | 13. Type of Report & Period Covered: Interim 7/72-6/73 |
| | 14. Sponsoring Agency Code |

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

This report presents material developed as part of a long-term "Interactive Computer-Aided Techniques Study". The report outlines the stages of development in the utilization of interactive graphics as a tool for Computer-Aided Design and Engineering (CAD/E). A series of characteristics are presented which are of significance to the designers and users of such systems and a series of questions of evaluative interest posed. These questions are intended to delineate the extent to which a system under examination achieves its stated design objectives. The characteristics are grouped in accordance with the nature and complexity of the experiments which would need to be conducted to establish values for them. The report suggests selected characteristics of particular interest and suggests the design of experiments for examining them in detail. The report makes specific reference to the MEDEA design terminal concept under development within the Graphical Systems and Technology Branch of ECOM.

17. KEY WORDS (Alphabetical order, separated by semicolons) Characteristics; computer-aided design; interactive graphics; man-machine interaction; performance measurement

| 18. AVAILABILITY STATEMENT | 19. SECURITY CLASS (THIS REPORT) | 21. NO. OF PAGES |
|---|---|---|
| [XX] UNLIMITED. | UNCLASSIFIED | 33 |
| [ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS. | 20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED | 22. Price |

USCOMM-DC 66244-P71