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The effect of data position on the performance of casual VDT users

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THE EFFECT OF DATA POSITION ON THE PERFORMANCE OF CASUAL VDT USERS

by

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DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

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THE EFFECT OF DATA POSITION ON THE PERFORMANCE OF CASUAL VDT USERS

A DISSERTATION

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FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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Abstract

This is an experiment in human-computer interaction. An experiment was devised to measure the Response Time and Error Rate of casual users while searching for a textual objects from unfamiliar VDT screen formats.

A Positional Effect was discovered which implies that where an item is placed is an important predictor of Response Time. An item appearing in the lower-right quadrant requires considerably longer to locate than an item appearing in the upper-left quadrant. No correlation was found, however, between Position and Error Rate.

Corroborating earlier work, Character Loading was found to also be a powerful predictor of a subject's ability to correctly locate a datum of interest.

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Acting Chairman, Section on Medical Information Science

Professor of Medical Psychology

Thesis Committee Chairman

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1. INTRODUCTION

1.1 AN INTRODUCTION

The rate at which workers perform tasks accurately is a major concern of any enterprise. With the industrial revolution came the requirement that workers perform repetitive tasks with a high degree of precision and at a sustainably high rate of speed. In certain instances, for example, in air traffic control and in modern clinical medicine[1], the consequences of a misstep can be severe.

1.2 STATEMENT OF THE PROBLEM

While elaborate theories of human reliability have been formulated, very little hard data has been collected in an area of increasing importance– the use of online computer systems by casual, largely untrained users.

This is a work in the area of the human-computer interface. It examines empirical data in order to provide an insight into the nature of human performance when performing a specific visual search task.

It will examine two human performance variables, search time (called Response Time below) and Error Rate.

1.3 GOALS OF THIS RESEARCH

The goal of this research is to identify quantitative measures of factors which contribute to variances in the human performance of casual users in scanning and decoding information presented on alphanumeric VDT displays.

An ultimate goal of this line of research is to provide insight into how to design the "ideal" screen, one which can be scanned and decoded instantly, and without error. While this goal is of course unattainable, given the ultimate limitation of the human information processor, any significant advance toward this end could reap huge benefits for the information workers of today, and tomorrow.

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1 Examples of such tasks include scanning clinical laboratory results, radiology reports and patient demographic data.

Another possible outcome of such lines of research is the design of rule-based software tools which could ultimately find the strategy which yields an optimal screen design, thus replacing the human drudgery of screen design, by automating the menial, and time consuming, task of deciding where to place each datum on the screen.

1.4 MOTIVATION FOR STUDY

With few exceptions, software engineering has progressed independently of the emerging body of knowledge available from the field of cognitive psychology.

To put it bluntly, software design methods have emerged through a largely seat-of-the-pants approach to their formulation, resulting in litanies of crude guidelines which exist without authority and verification.

For many years, as a software designer, I have been the unwilling recipient of that advice. For seemingly countless more years, I have been a user of that software, which has tempted me many times to say: SOMETHING HAS TO BE DONE ABOUT THIS! So many screen designs, produced even in professional applications, assault the eye and insult the mind.

There are classes of users however that can, and do, simply say "to heck with it" and give up, and force a retreat to more malleable methods. One such class of users is the **casual clinical user** of computer systems. For example, if laboratory results are not decipherable when viewed online from a computer, the clinician can, and does, retreat to those more manual tools which could be decoded more readily.

Screen designs have been so poor, in my opinion, that this fact may have contributed to the very slow proliferation of computer acceptance among clinicians. Certainly clinical applications trail those of banking, or the airline industry, or market research, by many years.

1.5 INVESTIGATION METHODOLOGY USED

One can imagine perhaps two general classes of experiments which could be conducted in an investigation in this area of study. The first would be a strictly controlled experiment, using contrived screens which vary a single parameter very precisely. This is of course the classic adoption of the scientific method.

The second general class, following an engineering paradigm, would use alternative designs from a single application and measure the difference in performance between them. As a result of such an experiment, an application builder could choose from among competing designs (the "wind tunnel" approach) a design which was best for his specific application.

In our case, the methodology used can best be described as a combination, or perhaps a compromise, between the two approaches, for neither of the above experiments ideally suits our purpose. We are not interested in a specific application, but rather in more general principles. Therefore we must reject a strictly engineering approach. The classic scientific experiment fails us also, since it is doubtful whether any usable principles could be extracted from an analysis of the results of experiments using only contrived screen designs.

Instead, we choose to use large numbers of "real" displays, captured from existing applications in a number of fields. We chose to use large numbers of subjects, since we realize many data points will be required.

1.6 HYPOTHESES

Descriptive analysis of the experimental results reveals huge differences in human performance levels among the various screens tested. Through many iterations of analysis, involving literally scores of hypotheses, an attempt was made to discover factors which could account for these differences.

The investigation centered on the following general categories of factors:

1. Loading factors
2. Grouping factors
3. Æsthetic factors

In the course of these investigations intermediate results were reported regarding the various techniques employed. [STREV84, STREV85].

1.7 A PREVIEW OF RESULTS

No evidence was found that if a display looked "nice" (i.e. was subjectively judged as "attractive" by a user, or could be said to exhibit characteristics of beauty by standards of established æsthetic measures) that such a display design would inspire high(er) levels of human performance. An example of such a result was an investigation of the classic æsthetic measure of Balance. No evidence could be found that a more balanced display was more readily decoded than an unbalanced one.

The experiment which we are about to describe does however yield strong evidence of the existence of a factor, which is a new and original contribution to knowledge in this area. We shall describe and document the existence of a Positional Effect. This factor contributes significantly to the variance observed in this experiment.

Another finding closely parallels earlier investigations of the Loading Factor, a factor which has been the most studied. The fact that the results from this experiment so strongly corroborate earlier work in this area lends additional credibility to the methodology used here.

A discussion of the implications of our findings to practical design will conclude this work.

2. SCREEN DESIGN: A HISTORICAL PERSPECTIVE

2.1 A PHILOSOPHICAL BEGINNING

The notion that *form follows function* is an underpinning of Western civilization. Æsthetics introduced the notion of order, proportion, balance, rhythm, and a host of other factors which define beauty. While it was never assumed that a beautiful object was necessarily a functional one, man's more practical applications of æsthetic principle to modern engineering and architecture seek to offer function while accommodating form. The roman arch offers rhythmic form along with prodigious load-bearing characteristics. The gothic spire provides a practical way for man to build toward the heavens.

Plato (437-347 B.C.) viewed the practice of art as a craft that produces something, not simply art in the abstract. However, Plato probably thought of beauty (and therefore function) as a single property that must be directly experienced and therefore not analyzable or definable. [BIRK33]

Gustav Fechner (1801-1887), the originator of experimental æsthetics, sought to solve æsthetic problems in the laboratory. He used the colorful term "æsthetics from below" to describe his experiments with shape, form, and color. From experimental æsthetics sprung the areas of experimental psychology and Gestalt psychology.

2.2 THE CONTRIBUTION OF PSYCHOLOGY

2.2.1 The Psychology of Gestalt

The Gestalt school of psychology (Germany, 1920's) suggests factors which determine how individual elements are grouped together during perception into wholes or *Gestalts*.[1] [SPOE82] These psychologists observed certain fundamental, unlearned tendencies of visual perception which are used to organize a visual field based on the arrangement and relative location of elements in the field. They designed experiments to demonstrate a number of principles related to this phenomenon which later became known as the Gestalt Principles of Organization:

- The principle of *proximity* suggests that clustered objects are more likely to be perceived as related than are distant objects.

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1 It is interesting to note that Gestalt is the German word for "form".

- The principle of *similarity* suggests that objects of similar form will likely be perceived together.

- Other principles include those of *common fate,* of *good continuation,* of *closure,* of *area* and of *symmetry.*

2.2.2 Experimental Psychology and the Visual Search Task

Visual search tasks have occupied many experimental psychologists. The task of discriminating target from background is of interest to military tacticians, radiologists, air traffic controllers and many others. Without the power to discriminate between stimuli, human perception would fast be overloaded and confused. Most germane is the work of Gottsdanker (circa 1960) who listed many factors involved in search. [GOTT787] One search determinant, which he describes as the "competition determinant", refers to the situation in which a target is readily distinguished from its immediate background. [BLOO73] This discriminant describes, but does not explain, how humans are able to rapidly filter incoming stimuli and just as rapidly attend to an item of interest.

2.2.3 Eye Movement Studies and Visual Information Processing

Other inquiries have focused on eye movement as a way of understanding how such discrimination is made. Picking out the incongruity of an octopus at the periphery of a barnyard scene [LOFT81], subjects' eyes abruptly perform saccades[1] to attend to the incongruous item. Stark reminds us of the complexity of this problem and remains uncertain whether this process is a parallel, one-step process or a serial, step-by-step one. [NOTO71] The process is often modeled as a serial function however, and it is this simplification which gives rise to today's school of Information Processing.[2]

2.3 THE CONTRIBUTION OF TYPOGRAPHY

The medium one uses does of course dictate important constraints. The task of layout for a drawing is clearly different from that for a newspaper page or for the placement of instrumentation in an airliner's cockpit. As functional requirements are levied on a design, they circumscribe the possible forms which can be used.

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1 Saccades are rapid, abrupt eye movements from one fixation to another.

2 I purposefully make no distinction here between the term Information Processing as used to define a school of psychology and the term used to describe the actions of a computer.

With VDT terminals, as with the printed media, the principal human activity is reading. It is typography which first provided certain taxonomies of textual formats. While these hardly date back to Gutenberg (1454). Literature on this subject can be found back to the early part of this century. [BONS68]

It was also typography which introduced the application of quantitative measures to the syntactic properties of textual material. The "mathematicization of æsthetics" is the term used by Bonsiepe [BONS68], as he provides complex formulae for the computation of order and distribution on a printed page.

2.4 THE ADVENT OF THE COMPUTER

With the advent of the computer came a textual blizzard. First, the ubiquitous printed report flooded the so-called paperless office. The formats for these reports however raised few new challenges above those raised by the format of any other printed material.

It was the VDT, that orphan of World War II radar technology, which caught designers unaware. The VDT was a convenient, but altogether different, output medium. It had a strange shape[1], was difficult to program, and was often hard to read. While the VDT technology of, say 1948, was sufficient to display radar blips with some resolution, it had to mimic text by drawing complex secants on the face of the tube[2]. [DEGR70]

Much of the early experimentation with VDT screens, in fact a great proportion of today's experimentation as well, deals with the physical problems of this adopted device: its phosphoric characteristics, its flicker/refresh dilemma, its color, its character set(s), its sharpness and focus and so on.

With the advent of interactive information systems, the VDT was transformed from being strictly an output device into the chief interface between man and computer.[3] Indeed the focus of interactive systems became the VDT and the textual forms which were created and presented upon it.

The VDT itself is somewhat of an enigma, for it represents at least two distinct media. As a 'glass teletypewriter', the VDT is a scrolling device which can playback an ongoing conversation without concerning itself with overall form. The reader usually concerns himself only with the current line, or few

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1 The tubes were round. Later they became rectangular.

2 The first non-experimental use of the VDT as an output device appears to be the SAGE system, circa 1952, which was a command-and-control early warning system.

3 Apparently the first interactive use of the VDT was in 1951 at M.I.T. using the Whirlwind I computer.

lines, of text at any one time. The remainder of the visual space is merely an archival medium, with the oldest information scrolling off the top of the display.

At some point, the VDT began to be viewed as a page device, that is, one which presents a complete page at one time, to be viewed as a unit. One is left to speculate how this came about. Perhaps the speeds of transmission began to overcome man's comfortable reading rate. Or perhaps technology simply changed. In fact certain newer VDTs could *only* conveniently function in page mode.[1] While display technology burgeoned, display application concepts lagged far behind.

2.5 THE ADVENT OF METRICS, AND TOOLS, AND SOFTWARE PSYCHOLOGY

Designers were then forced to deal with the visual space of the page-oriented VDT as a whole. The space on which a designer could create, while resembling a printed page, had some very significant differences:

(1) The size of the space was very small. The 24x80-character (1,920 total characters) format of the VDT may have been adequate for scrolling information at slow speeds. However, it presented a visual page of very small proportions. By contrast, a two-page newspaper spread in the *Wall Street Journal* is filled with about 60,000 characters. Thus the VDT page provides only a small peephole onto very large databases.

(2) The topology of the VDT space was very different. There were few visual cues or landmarks around which to fashion the design. It didn't have columns or rules[2]. It didn't have a variety of font styles or point sizes. Least of all, it had few built-in conventions to follow; error messages, for example, could be pasted anywhere on the screen with equal alacrity.

Not surprisingly, most of the early attempts to utilize this new medium were naïve, almost farcical. Screen designs between applications frequently bore no resemblance to one another. Even within a single application, a user was often required to deal with different designs from screen to screen.

With experience, designers, and computer users as well, observed that there seemed to be some "good" designs, a vague notion at this point. Human

1 For example the IBM 327X terminal family, circa 1970.

2 Column and rule marks help guide the eye across dead space.

performance seemed to improve when dealing with the "good" ones, and to deteriorate rapidly otherwise.

The application of metrics and software tools, which were being applied to other areas of computer science, was clearly needed. The metric, a device of engineering, is a convenient way to describe a vaguely understood process. Metrics for programmer productivity, for instance, were fashioned. [SHNE79] Metrics to describe the nesting level of a structured program were created. [GILB77]

Along with metrics came a heightened awareness that software tools were needed throughout the design process, especially for this new genre of interactive system activities. [WASS82] In his work Wasserman conceives of a highly automated environment which provides constant, almost tactile, feedback to the designer about the software design being generated.[1]

2.6 CURRENT STATE OF THE ART

Unfortunately, in screen design, one has been left with very little assistance. There have been two approaches to providing guidance.

2.6.1 Some Experimental Results (the bottom-up approach)

The first has been to offer empirically validated results dealing with a specific situation. There are, for example, results which suggest how many items should appear in a menu. [TEIT83, LEE85] There are results which suggest whether tabular data is best represented horizontally or vertically. [COFF61, WILL66, WOOD72] And there exist some data on certain factors of screen design, most notably the Loading Factor.[2] But results are sparse, and often not easily generalizable to a broad range of design problems.

2.6.2 Guidelines for Screen Design (the top-down approach)

On the other hand there exist many lists of guidelines which have been offered by practitioners and psychologists. Compilations of guidelines have varied from lists of only several to mammoth lists of several hundred[3]. They have likewise varied from being quite specific (and thus applicable in only a few special cases) to general (hoping to more broadly applicable).

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1 It has been suggested that this approach conjures up an image of a "programmers' cockpit."

2 We shall describe these in detail when we address the specific factor (see Chapter 6).

3 Smith and Mosiers' work included 162 such guidelines! [SMIT84] It is doubtful that such lengthy lists have practical value to designers or could be enforced by a design manager.

Presented here are samples of those guidelines. Note certain similarities between the lists; it is that similarity which has suggested factors for study in this project.

Martin [MART73] suggests that one:

a. Display a small amount of information at one time.
b. Have one idea per display.
c. Use formats designed for clarity.
d. Strive for similarity.

A frequently cited list is attributed to Stewart [STEW76 p.142-3]. His list of six characteristics is terse:

a. Logical sequencing
b. Spaciousness
c. Relevance
d. Consistency
e. Grouping, and
f. Simplicity.

Another list, by Siegel and Fischl [SIEG71 p.474-6], results from an experiment in which an attempt was made to isolate factors which determine the legibility of a complex display:

a. Stimulus numerosity
b. Structure scanning
c. Cognitive processing activity
d. Critical relationships
e. Cue integration
f. Contextual discrimination, and
g. Primary coding.

This is by no means an exhaustive list of guidelines which have been suggested. They do represent several attempts at providing a usable taxonomy. Unfortunately these lists produced only crude guides to the designer.

2.7 CONCLUSION

It is against this historical perspective that we now can fashion a description of the work of this thesis. Technology continues to move – toward bit-mapped displays, windows, color displays, etc. Yet the the understanding of the screen design process itself is still poorly researched. It is the goal of this work, while working with the older, more "stripped down" VDT, to make a small contribution toward understanding it and the more complex devices with which succeeding researchers will no doubt find themselves.

3. EXPERIMENTAL DESIGN AND PROCEDURE

3.1 INTRODUCTION

Subjects were presented VDT images and asked, via synthesized voice, to locate a particular datum of interest. The time to accomplish this task was logged automatically for later analysis.

The experiment was conducted to gather empirical data concerning a particular human performance variable related to an unlearned visual search task.

The experiment simulates the situation of a user confronted with an unfamiliar display for the first time, or that of a casual user who infrequently confronts a computer system and who must therefore substantially re-learn his role at each session.

The experiment involved 98 subjects, 34 screen designs, 114 discrete questions about these designs, and yielded 6,810 observations.

3.2 DESCRIPTION OF THE EXPERIMENT

3.2.1 Gathering Appropriate Screens

Subjects were presented replays of actual screen designs which had been captured directly from running computer applications. By choosing real displays, rather than contrived ones, the ability to generalize to real-world situations is enhanced. Software engineering principle requires that the domain of experimentation parallel that of any conclusions to be drawn later. [BAIL82]

3.2.1.1 Screen domain

Screen topics were chosen from a variety of disciplines—from business, accounting, demographic, medical, university, and process-control applications. These screens are representative of a large number of computer systems now in existence. It is highly unlikely however that any subject would have previously encountered any of the designs which would later be seen in the experiment.

Certain constraints were placed on the choice of displays to appear in the experiment:

1. Screens must conform to the constraints of the common 24x80 alphanumeric display device.

2. No video attributes could be employed (such as reverse video, underlining, blinking or half-intensity) since the implementation of these capabilities differs substantially among display device brands and models.

3. All alphanumeric character combinations were allowed including upper and lower-case character sets and certain special characters.

4. Displays were data-oriented and often tabular in nature.

3.2.1.2 *Software Tool to Capture Screens, THE SAMPLER*

In order to assure the fidelity of the screen images[1], a software tool was created to directly capture them from executing processes.

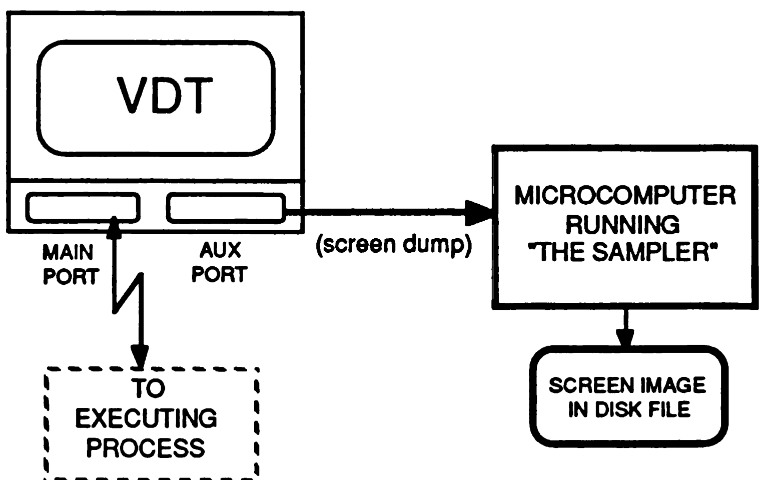

Fig. 3.1 A block diagram of THE SAMPLER, a software tool devised to capture screen images directly from executing application processes.

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1 It was on occasion necessary to touch up the image of a captured screen to insure confidentiality, or to insure a unique "hit" in the experiment – trials were designed such that no false-positive results could occur, i.e. the correct response did not appear anywhere else as a possible answer. However, positions of data items were never altered, nor were any other significant characteristics.

During the execution of the host process, and upon command, the connected terminal's screen memory is dumped through the terminal's auxiliary port to a waiting microcomputer which stores the image, as text in a disk file, for later retrieval — for factor scoring, and for replay during the experiment.

3.2.2 Scoring the Screen Designs, THE EVALUATOR

Another software tool, dubbed THE EVALUATOR, examines the canonical form[1] of each screen design and scores each factor under study.

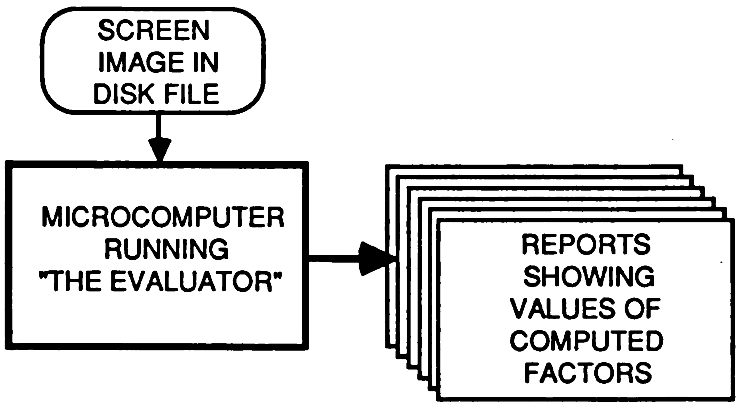

Fig. 3.2 A block diagram of THE EVALUATOR, a software tool which examines the canonical form of each screen design, scoring each factor to be studied..

Using a software tool facilitates the task of introducing new factors or specifying different computational methods for scoring an existing factor.

3.2.3 Experiment Description and Procedure

3.2.3.1 Subjects

Ninety-eight (98) subjects were recruited from undergraduate computer science classes at the University of Hawaii. A large number of subjects were required because large variances in response times among individual subjects were anticipated.

1 We refer to the designs' canonical form, since all analyses involve only the syntax of the design, not its semantics. Thus the analysis of each screen image can be thought of as "blind to content".

Approximately half of the subjects indicated they were, or planned to be, computer science majors. Approximately half were male, half female. All had had one or two years experience with various computer terminals, and were therefore familiar with the keyboard layout.[1]

Subjects were English-speaking and had declared English as their mother-tongue. Subjects were required to convince the interviewer that they speak English at home, that they think in English, and that they normally dream in English.[2] As a motivation to perform well, a prize of $50 was offered for the "best score". No mention of how that score would be computed was provided.[3] (The prize was later awarded.)

On acceptance, subjects filled out a questionnaire (see appendix A2) and were assigned a subject number. All later identification of subjects was made through the use of this number.

3.2.3.2 Experimental Protocol

3.2.3.2.1 Pre-testing activities and the experimental environment

Subjects were greeted at their appointed time. They read a statement describing the purpose of the experiment. (see appendix A1) In a room adjoining the experimental chamber, they were instructed to listen attentively to a tape recording which contained passages from the Constitution, and various famous quotations, read by the voice synthesizer they would encounter later in the experiment. The tape lasted approximated ten minutes. Subjects were invited to listen again if they so choose.[4]

Subjects then listened to a tape containing the actual vocabulary of the experiment, reading along from a written sheet containing the same phrases. This tape was heard a second time, this time without the written sheet.

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1 Since subjects would be required only to strike a single key during each trial, typing speed was not a particularly worrisome factor. Later analysis showed no correlation between a subject's performance and his/her declared typing ability (See Appendix 2, p.2). Further analysis did not provide any evidence that some (answer) keys were harder to locate than others.

2 This was crucial because of possible confounding role of the voice synthesizer in the experiment. This problem is particularly worrisome in multi-cultural Hawaii.

3 No specific instructions were given regarding guessing. The prize money was given as a motivation to perform well.

4 However, if the subject indicated any difficulty in understanding the synthetic speech, the results from his session were later ignored. Six subjects were disqualified as a result of this screening.

Subjects were then escorted into the room containing the experimental apparatus. The room was a 8x10-foot room which was once a faculty member's office. The ambient noise level in the room was low and the subject wore headphones. The room lacked windows, so no direct outdoor lighting was present. Artificial lighting, from two fluorescent fixtures, was strictly controlled, avoiding glare on the face of the VDT display screen. During the experiment the door to the room was closed to avoid distraction. Only the subject was in the room during the session. Subjects were not recorded on videotape. Temperature levels were closely monitored to assure comfort.

Subjects' heads were not restrained, but attempts were made to suggest a standard sitting position (a chair without coasters was used), with the subjects' eyes being approximately eighteen inches from the face of the display. The height of the display was adjusted so that the subject looked slightly down into the display (at roughly 10^{o}) to avoid neck or back fatigue. This is the recommended ergonomic position. [BAIL82]

3.2.3.2.2 The experimental apparatus

All subjects encountered precisely the same placement of the experimental apparatus:

3.2.3.2.2.1 The VDT and its keyboard

The VDT is a Televideo 950 display with a green phosphor. Its display area is 5-5/8" x 8-3/4", a common dimension of many existing VDT tubes. The VDT had been aligned to assure proper focus and a lack of distortion. The brightness of the display was strictly controlled.

This particular model offered these advantages:

1. It was already familiar to most subjects who had used it in programming exercises.
2. It contains a four-page screen memory, which allowed the control program to build the next trial in screen memory ahead of time.
3. It offers an escape sequence which allows the control program to instantaneously turn the display on and off.

The device has a detachable keyboard, which facilitates comfortable placement of the keyboard, accommodating both right-handed and left-handed subjects. No distinction was made between upper and lower-case keys, thereby obviating the need to use the shift or shift-lock keys. The keyboard is altered in one slight way with the spacebar being relabeled to provide the needed REPEAT/SKIP key.[1]

3.2.3.2.2.2 The Voice Synthesizer

A voice synthesizer presents aural cues to the subject. The choice of this method is crucial to the design of the experiment. It is well known that humans possess a short-term visual memory which is quite adept at pattern matching. [RICH80] By presenting instructions over a different sensory modality than the one used to perform the task, the subjects' ability to do visual pattern matching is inhibited. Most psychological models suggest that visual pattern matching occurs at an early stage of the perceptual process, and that there are specialized processing mechanisms for each modality of sensory information. [NORM77 p.66] Providing aural cues, instead of visual ones, forces the subject to encode a higher-level representation of the request, and to formulate a search strategy which cannot rely on visual pattern matching abilities. If visual cues had been presented, the response time would measure a largely perceptual process which is different from the cognitive process we wish to study.

The voice synthesizer is the Votrax 200 Personal Speech System, which employs the popular SC01 phonème synthesizer chip. It is driven by a serial port connected to the computer which controlled the experiment. The subject wore lightweight headphones which were connected to the synthesizer. The volume control was adjusted by the subject for a comfortable listening level.

3.2.3.2.2.3 The Computer and THE EXPERIMENTOR

THE EXPERIMENTOR is the computer program, running on a microcomputer, which controlled the experiment and logged the results. To assure accurate measurement, the program relied upon a calibrated clock accurate to 1 msec.

1 This key is the only one altered in any way from the normal keyboard configuration. This choice of keys was made for several reasons: First, the space bar is the largest key and is therefore easily struck. Secondly, the character "space" cannot be an appropriate response to any question, and therefore the subject's intention is never ambiguous.

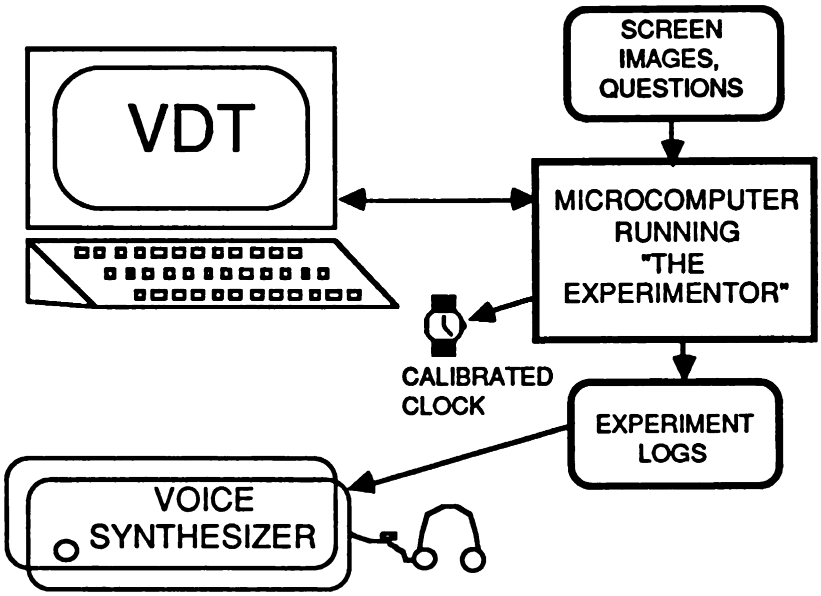

Fig. 3.3 The EXPERIMENTAL APPARATUS, including the control program, the VDT (presenting visual cues), and the voice synthesizer (presenting aural cues).

The chief tasks of the program were:

1. To randomize the presentation.[1]
2. To present visual screen images and aural cues.
3. To time the subject's response and log the results to a disk file for later analysis.

The final pre-test activity consisted of a short practice session using the apparatus. The pre-test was realistic in every detail, except that its eight screens differed from those used in the experiment itself.

3.2.3.3 *The Experimental Protocol*

A session consisted of presenting a series of trials, consisting of a screen format (on the VDT) and a related question (through the voice synthesizer).

These are the steps in each trial:

1 The computer's random number generator was carefully checked to assure the required degree of randomness.

1. A question, representing a visual search task to be performed, is presented by the voice synthesizer through the headphones, for example, "CITY."[1] The subject could request that the question be repeated any number of times by hitting the REPEAT key.

2. After a short pause, sufficient to allow decoding of the request, the display instantaneously flashes with an image to be searched for the target item.[2] The clock is started.

3. The subject now performs the visual search task. He responds by depressing the key corresponding to the first character of the answer.[3] The voice rewards with a simple "CORRECT", the clock is stopped, and the result of this trial is recorded in the log.

4. Other situations arise at this point when the response is not correct, or the answer is not attempted:

- If the subject wished to skip (for now) this trial, he was instructed to depress SKIP. The trial was aborted, the action logged as a SKIP, and the next trial begun.

- Or if, after 20 seconds, the trial had not been completed, the trial was aborted, the action logged as a TIMEOUT, and the next trial begun.

- If the answer was not correct, no reward message was presented, the action was logged as INCORRECT (and time recorded), the trial recycled (possibly to be repeated again later), and the next trial begun.

5. The session ends when all trials have been answered correctly, or after a total of 80 trials. At the conclusion, the voice offers a "THANK YOU", and a THANK YOU message is displayed on the VDT.

6. Each subject is debriefed, and asked to record his impressions of the experiment on a questionnaire (see appendix A2). The subject was thanked, and dismissed.

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1 These aural prompts are not technically questions since they are not in the form of a question. Aural material was purposefully made as terse as possible.

2 The screen image has already been sent to the VDT's memory, so the subject does not see the computer "paint" the display image. A compilation of the screens and questions used can be found in Appendix A3.

3 For example, if the request was to locate CITY and SAN FRANCISCO (either prompted or not prompted) appeared, the correct response is to depress the "S" key.

3.2.3.4 *The Experimentor's Logs*

Each trial, or aborted trial, results in the creation of a record in the log (see appendix A4), which is written to a disk file by the control program. Each record contained the following information about that trial:

IDENTIFYING DATA:

1. SJ The unique subject identifier number.
2. EV The chronological event number for this subject. (The first trial attempted by this subject would contain the number one, and so on.)
3. TRIAL The trial number of this trial. Each screen/question pair had been assigned a trial number.
4. SCR The screen number used in this trial.
5. QUS The question used in this trial. (Note that certain questions were used on more than one occasion.)

SECONDARY OUTPUT DATA:

6. NVOIC The number of times the question was repeated by the voice (see step 1 in 3.2.3.3 above) in this trial. With this data it was later possible to determine how difficult each question was to decode.
7. NPREV The number of times this trial had been previously attempted by this subject. To avoid frustration, no trial was ever presented more than four times to a subject.
8. CANS The correct answer (i.e. the expected answer) for this trial.

PRIMARY OUTPUT DATA:

9. GANS The given answer for this trial.
10. MSEC The response time, in msec, between the presentation of the display and the response of the subject.

3.3 SUMMARY

In this chapter, the experimental apparatus and procedures which were used to collect the data which are analyzed elsewhere in this dissertation was described.

Experimental controls were established to minimize noise wherever feasible. Special consideration was given the possible confounding effect of the use of the voice synthesizer.

Three software tools were designed, THE SAMPLER, THE EVALUATOR and THE EXPERIMENTOR in order to automate phases of the experiment.

4. A DESCRIPTIVE ANALYSIS OF EMPIRICAL DATA

4.1 INTRODUCTION TO DESCRIPTIVE ANALYSIS

We begin our presentation of empirical results by providing a descriptive analysis of the data collected in the experiment. The descriptive analysis will center on the two major factors of study in this investigation, Error Rate and Response Time.

4.2 ANALYSIS OF ERROR RATE

4.2.1 What is Error Rate?

Error Rate is an intuitive concept. In simplest terms, an error can be thought of as an incorrect response to a probe question. For example, if a subject responds by typing a "D" when the expected, correct response is a "B", an error has obviously been committed. If the subject were to make such a mistake 5 out of 100 trials, an Error Rate of 5% would be assigned to the subject. Likewise if a certain question was answered incorrectly by subjects 5 out of 100 trials, the question itself would be said to have sustained an Error Rate of 5%.

Recall that the following four actions are possible outcomes of an experimental trial:

1. A "correct" response (i.e. the expected response.)
2. A "wrong" response, which could conceivably occur as a result of a cognitive error, or as a result of a mechanical error (i.e. the subject made a typing mistake.)
3. No response (a timeout occurs).
4. A "skip" response (the subject elects to skip this question and thus to attempt it later.)[1]

In the following analysis of Error Rate, an error is defined as any response *except* a correct response–thus a wrong response, a timeout, and a skip are considered "equally incorrect".

---

[1] Recall that in the case of wrong responses, time-outs and skips, the question is recycled, and presented later, in random presentation, for a maximum of four trials.

4.2.2 Error Rate of Subjects

A Normal distribution of Error Rates would tend to support the assumption that the "n" of the experiment is sufficiently large to allow meaningful conclusions to be drawn later. Secondly, a well-behaved curve would indicate that the subject population was randomly chosen to include similar numbers of over-achievers and under-achievers.

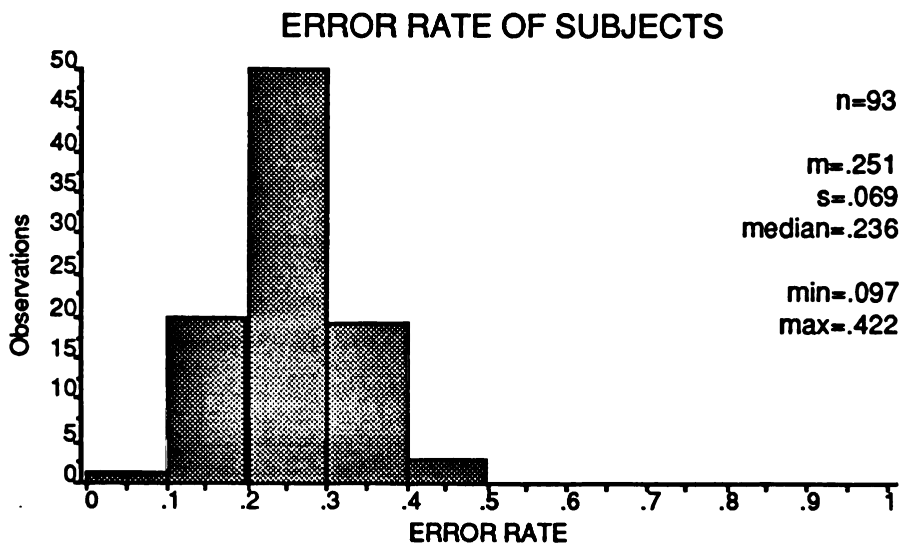

Fig. 4.1 A frequency distribution of the Error Rate of the 93 subjects tested in this experiment.

Indeed we obtain a well-behaved distribution of Error Rates among subjects. The average and median Error Rates are nearly identical. The typical subject failed to answer approximately one-fourth of trials correctly.

4.2.3 Error Rate Components

At first glance, the Error Rates reported above may seem extreme, with at least one subject scoring an Error Rate of more than 42%. This number is less surprising if one recalls the components of Error Rate:

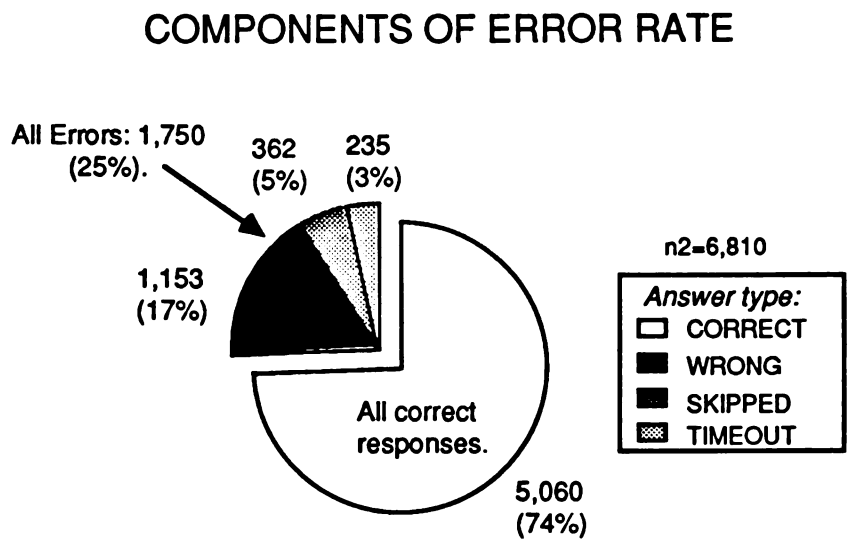

Fig. 4.2 The components of Error Rate include questions answered incorrectly, those skipped, and situations in which a timeout occurred.

About three-fourths of all responses were correct. Approximately one-third of the incorrect responses were discretionary, that is the subject chose to skip a question (until later) or did not respond within the allowable time (causing a timeout).

4.2.4 Error Rate of Questions

Just how good were the questions posed to subjects? We should certainly expect that some question domains would be more difficult than others:

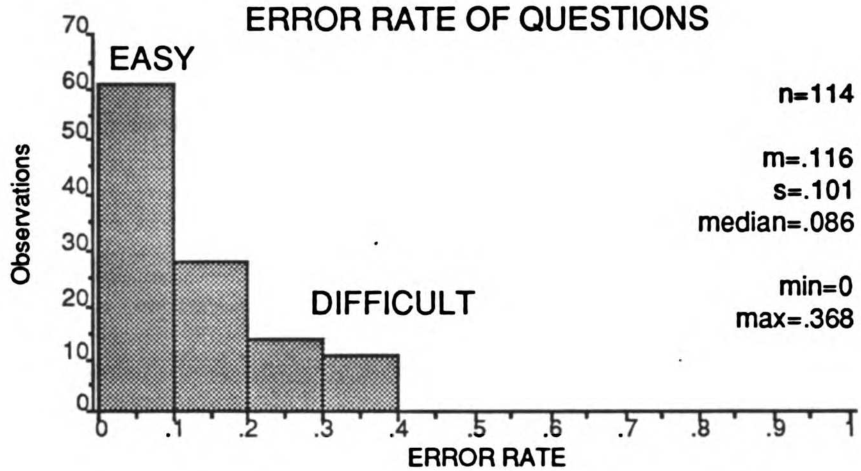

Fig. 4.3 The Error Rates caused by the 114 different questions used in the experiment. Note that certain questions are more difficult than others.

This distribution is well-behaved. Questions represented a variety of levels of difficulty, ranging from "easy" to "difficult". At least one question was answered correctly on the first trial by each subject. At least one question was not answered correctly on the first trial by any subject.

4.3 ANALYSIS OF RESPONSE TIME

4.3.1 What is Response Time?

The Human Information Processing paradigm suggests that a visual search task, such as that undertaken in this experiment, is described as a series of serial subtasks, each of which requires finite time, and may utilize a distinct processing skill. [LIND77]

The subtasks, the components of Response Time, can be described as:

t1. A screen image is presented. The control computer's clock is started.

t2. The screen image arrival is noted, and image processing begins.

t3. Cognitive decoding of the screen image begins.

t4. A visual search strategy is formulated (based on earlier aural decoding and understanding of the question posed).

t5. The visual search task begins. Eye movements accompany cognitive analysis of the success of the current search strategy. Search strategy is modified as necessary.

t6. The search task is completed.

t7. A motor request is made to depress appropriate key on computer keyboard.

t8. The key is depressed.

t9. When the key is fully depressed, the control program is interrupted, and the clock is stopped.

Individual components include times resulting from activating a combination of sensual, perceptive, cognitive and motor skills. The sum of these component times is referred to as the (total) Response Time. This experiment measures Response Time as:

$$\text{Response Time} = t9 - t1$$

Response Time is defined here as the elapsed time (in msec.) between the instant the display of the trial appears and the instant any key is depressed by the subject.

4.3.2 Choosing an "n"

Throughout this report, it is important to be mindful of the particular 'n' under discussion. There are several choices for 'n', the result of increased restrictions on the number of cases to be included:

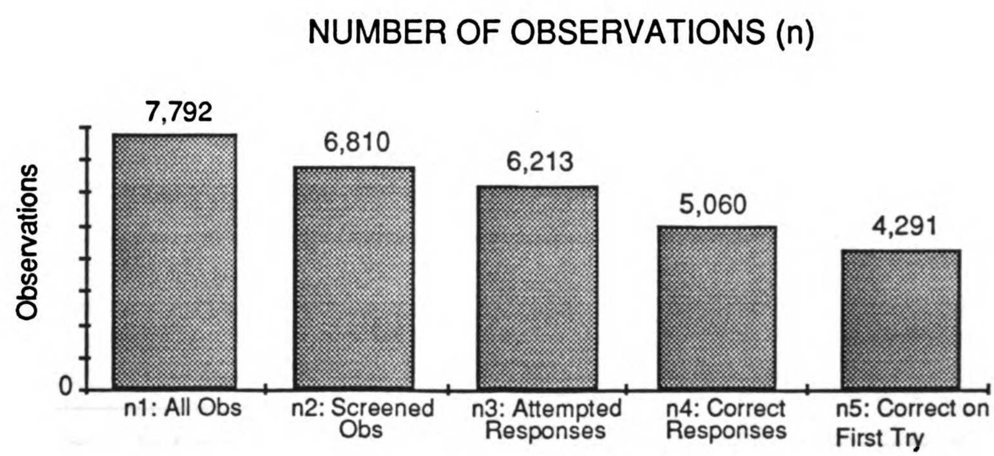

Fig. 4.4 The various n's occurring in this experiment.

n1. All observations collected in the experiment are included.

n2. N1 is restricted to exclude cases representing trials in which equipment failure, an interruption of the subject, or other failure of experimental method occurred.

n3. N2 is restricted further to exclude timeouts and skips.

n4. N3 is restricted to exclude wrong answers. Thus n4 includes all correct responses.

n5. N4 is restricted to exclude correct answers which required more than one try to complete successfully. Thus n5 represents correct responses on the first try.[1]

All analyses to follow will clearly state which n is used in that analysis.

4.3.3 Response Time Results

Fortunately frequency distributions of Response Time for both n4 and n5 are well-behaved. No discussion of significant difference can be attempted since n5 is a (dependent) subset of n4.

[1] Using n5 in certain instances is compelling, since it obviates any possibility that a subject's learning from prior attempts aids him in "short-circuiting" an otherwise full search strategy. Using n5 however significantly reduces the size of n, which might reduce the ability to extract generalized results.

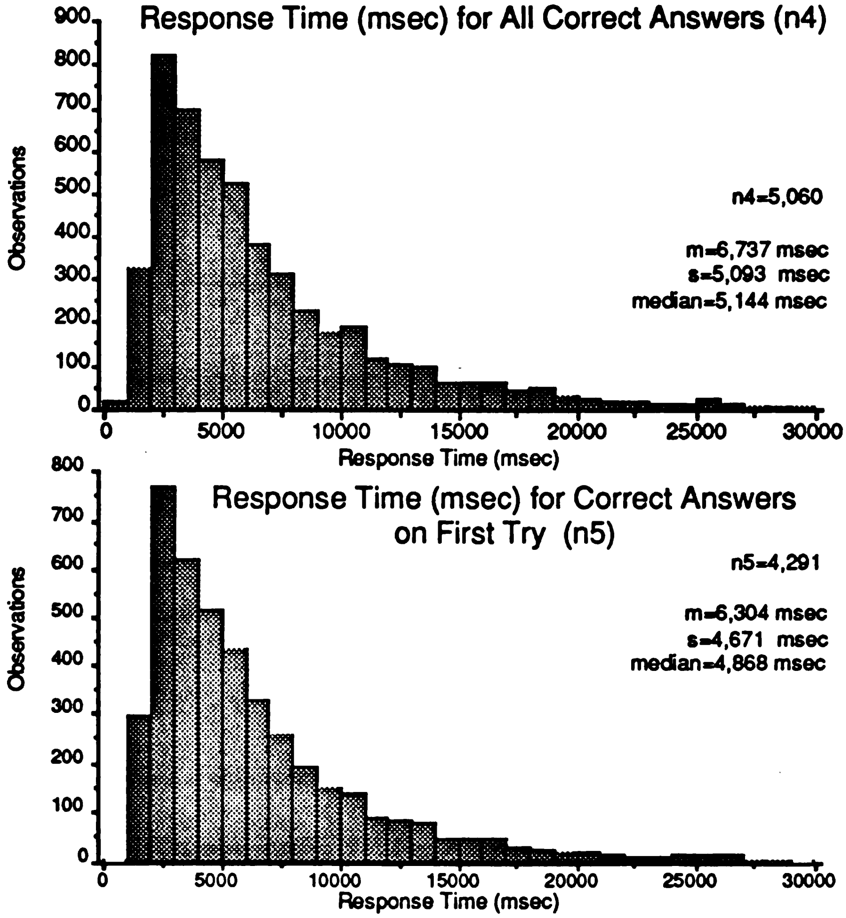

Fig. 4.5a The frequency distribution of Response Time (msec) for All Correct Answers for n4 and n5.

It is astonishing to realize just how long it does take a subject to answer a question, even a relatively simple one. Designers should be aware that it requires on the order of five seconds for a subject to complete a typical question.

> *A typical response requires on the order of five seconds to complete correctly.*

The well-behaved characteristic of the above distributions is even more marked when contrasted with the poorly formed distribution of response times to wrong answers:

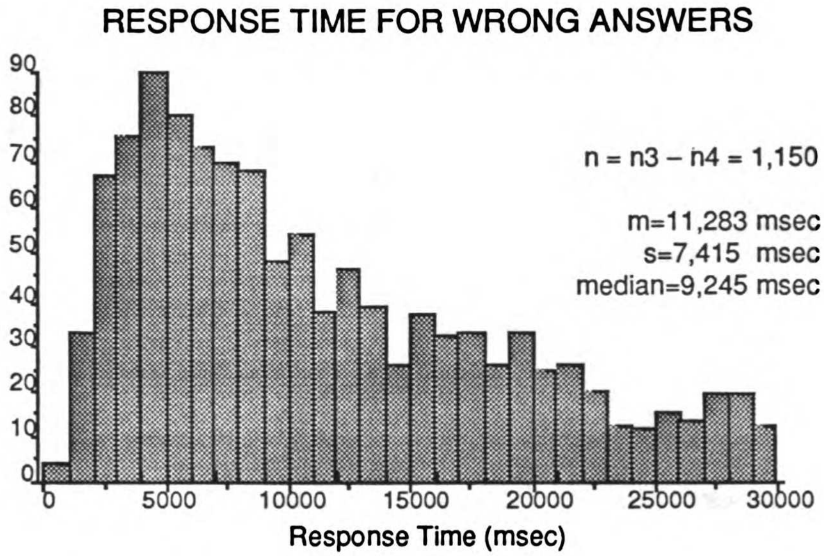

Fig. 4.5b The frequency distribution of Response Time (msec) for wrong answers.

Note that incorrect responses take considerably *longer* than do correct responses. Thus, not only do errors debilitate human performance by introducing inaccuracies into a task, but they waste time as well.

> *A typical wrong response requires on the order of ten seconds to complete. about twice as long as it takes to complete a correct response.*

4.3.4 Response Time of Subjects

How homogeneous were subjects in Response Time performance? Let us look at the frequency distribution of median Response Times for subjects:

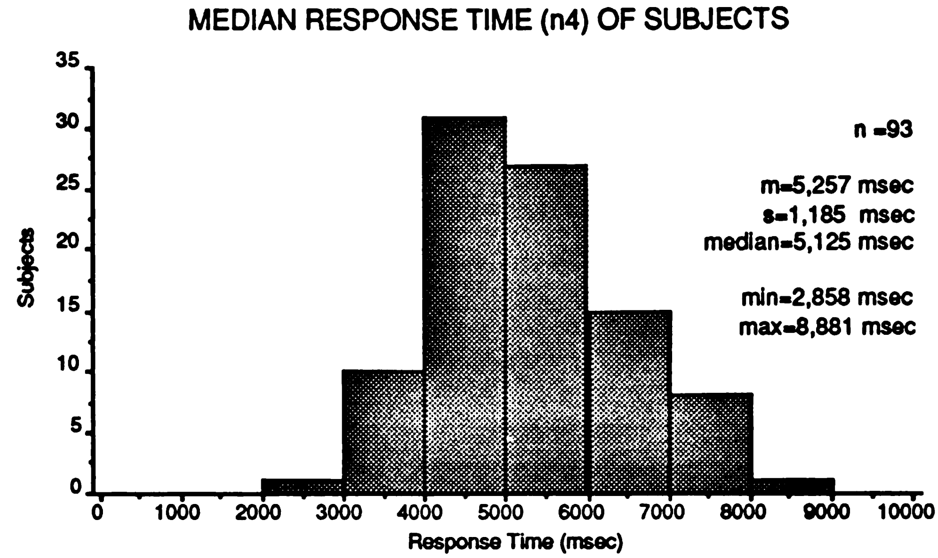

Fig. 4.6a Median Response Time (msec) for subjects for all correct answers (n4).

Note the regular nature of this distribution, and its Normal characteristics.

4.3.5 Response Time of Questions

We now turn our attention to the questions posed to the subjects. Like Error Rate (see Fig. 4.3 above), the questions demonstrate a spectrum of difficulty.

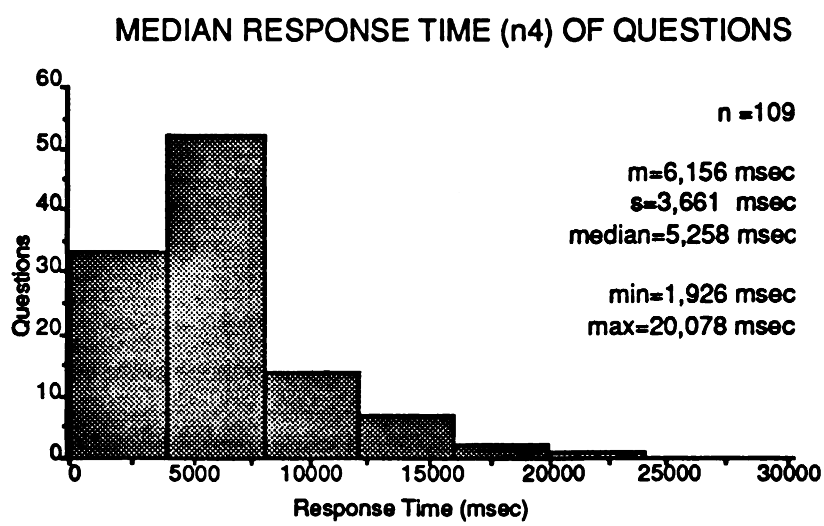

Fig. 4.6b Median Response Time (msec) of questions for all correct answers (n4).

4.4 THE RELATIONSHIP OF ERROR RATE TO RESPONSE TIME

How consequential is committing an error? We shall see that an error not only impedes accuracy, but also adds significantly to the execution time of the task as well.

Error Rate = .038 + 0.0014 x Response Time (msec) r^2=.231

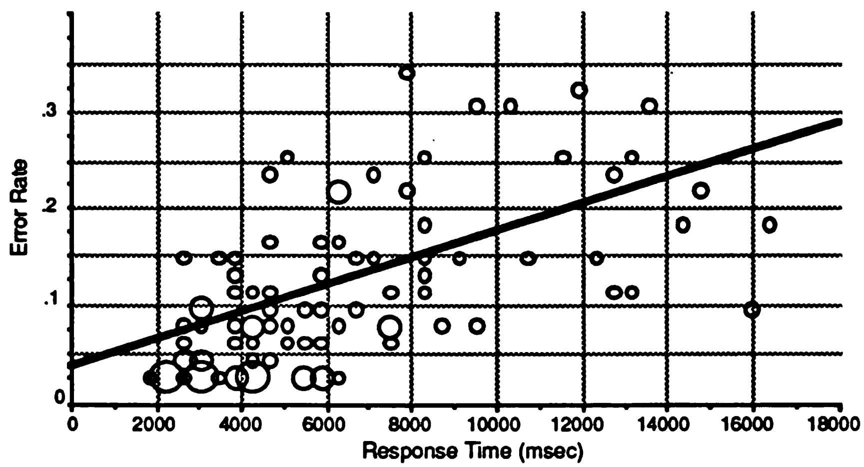

Fig. 4.7 Linear regression showing the relationship of Error Rate to Response Time (n3).

The longer the response time, the more likely an error is committed. Or, said another way, "easy" questions (those which one can answer quickly) result in few errors. Difficult questions both take a long time and introduce high error rates.

> *Error Rate and Response Times are correlated. The longer a question takes to complete, the more likely that an error will be committed.*

4.5 SUMMARY

The visual search task of a VDT display is a difficult task (high Error Rate) and takes a long time to complete (long Response Time).

In this chapter we have discussed how an "n" was chosen. We have provided a descriptive analysis of the two dependent factors in the experimental design, namely Error Rate and Response Time.

5. THE POSITIONAL EFFECT

5.1 INTRODUCTION

In the work that has preceded this [TULL83 and others], a principal assumption has been that there exist *global* parameters of screen design, that is, quantitative measures describing factors which are applicable across the entire surface of a display design. In this investigation it has become increasingly clear that *local* factor(s) also exist, and that they may explain large portions of the observed variance in subjects' response times.

The effect of position, i.e. the data location on the display surface, is described here. This factor, which we shall call the Positional Effect, explains more than one-fourth of the variance observed in this experiment.

5.2 DEMONSTRATION OF THE POSITIONAL EFFECT

If global factors were the sole predictors of interest, one could probe different locations on a display surface without encountering large differences in response time results. This is however clearly not the situation encountered in this experiment.

We shall demonstrate this effect by first examining a within-screen example which exhibits large differences in Response Time as the probe moves across the screen grid, and then by examining a between-screens example whose probe point remains semantically constant but appears in different positions in two different screen designs.

5.2.1 Demonstration #1: Four probes on the same screen.

Consider SCREEN–24[1], an example of a screen which happens to display similar data in all four screen quadrants.[2] It is relatively equally loaded in all quadrants. Four probe points were tested, one situated in each of its four quadrants:

1 See appendix A3 for a more accurate rendition of the screen.

2 Throughout this discussion, we will refer to the screen quadrants as:

Q1=Upper-Left	Q2=Upper-Right
Q3=Lower-Left	Q4=Lower-Right

```
Anywhere in CMIT                      Abbr   Name
                                       al     all

Parts of Disease Descriptions

     Abbr   Name                       Abbr   Name
      ds    disease                     ss    signs or symptoms
      at    alternate terminology       cm    complications
      et    etiology                    lb    laboratory
      sm    symptoms                    rd    x-ray
      sg    signs                       pa    pathology

Categories (Body systems)

     Abbr   Name                       Abbr   Name
      wb    whole body                  gi    gastrointestinal
      sk    skin                        ug    urogenital
      ms    musculoskeletal             en    endocrine
      lg    respiratory                 nv    nervous
      cv    heart                       mo    sense organs
      hl    hemic and lymphatic

RECOGNIZED CONTEXTS                               Press <RETURN> to continue
```

Fig. 5.1a SCREEN-24 Four probe points were tested on this screen, one in each of the four Cartesian quadrants. They are shown here as underlined letters.

In Quadrant 1 (Upper-Left), an average subject required just 3,674 msec. to locate the datum of interest. In Quadrant 4 (Lower-Right) it took almost three times as long, 10,628 msec. It is unreasonable to overlook this large *local* difference. Examples such as this led us to the conclusion that it is impossible to overlook this local factor when examining predictors of response time.

The results from the four quadrants of this sample screen are summarized below:

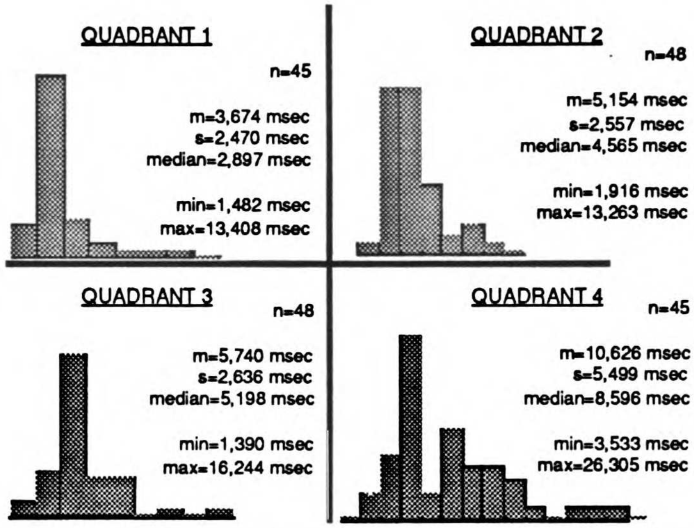

Fig. 5.1b SCREEN-24 Distribution of Response Times in the four quadrants of SCREEN-24 (n4).

Two phenomena are readily apparent in this demonstration. Notice how rapidly performance deteriorates as the probe point is placed further away from Upper-Left. Notice too how variance increases as the probe point as moved, as the eye is forced to wander about the field looking for the target.

It is also interesting to note how well-behaved the distributions appear to be:

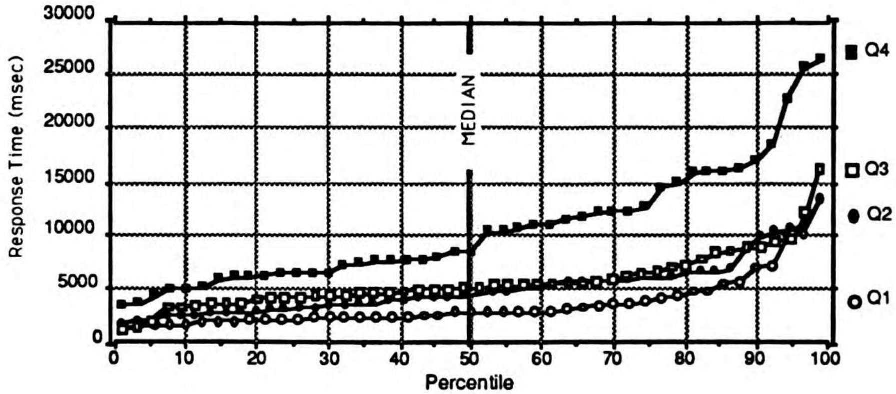

Fig. 5.1c Percentiles of Response Time in the four quadrants of SCREEN-24 (n4).

Significant differences (p<.01) exist between all four quadrants except between Quadrants 2 and 3:

Unpaired t-values of Response Times Between Quadrants of SCREEN 24

	Q1	Q2	Q3
Q2	t= -2.836 p= .0028		
Q3	t= -3.894 p= .0001	t= -1.105 p= .13	
Q4	t= -7.735 p= .0001	t= -6.215 p= .0001	t= -5.517 p= .0001

Fig. 5.1d Results of t-Tests between quadrants for SCREEN-24 (n4). Significant results (p<.01) are shown unshaded.

5.2.2 Demonstration #2: Identical probes on two different screens.

The observation that placement, or position, of a datum significantly affects response time was made repeatedly. In fact no screen design studied yielded consistent results across its face.

As a further demonstration of the positional effect, consider a within-screens example: SCREEN–31 (Fig. 5.2a) and SCREEN–34 (Fig. 5.2b). This time the same datum is sought ("Patient's Last Name"). In SCREEN–31 that datum is located in the extreme corner of Quadrant 1 (Upper-Left), while in SCREEN–34 it appears in Quadrant 4 (Lower-Right). Note that a "prompt" does not appear with the patient's name in either case, and that both names are formatted identically (as last-name, first-name):

```
STEWART, MARY SOVONIA          0647573-6    CLINIC:RDC  DOCTOR: WHITINGOKEEFE
==============================================================================

  PROBLEMS/MANIFESTATIONS      STATUS    INFO2      DATE     UNITS     ONSET
---------------------------  --------  --------  --------  -------   --------
 1.1 POLYMYALGIA RHEUMATIC*    +/-      ACTIVE    02-03-83            1978-
11.    WEAKNESS (UPPER EXT)    0/0                02-03-83  0-4 UE/L  1977
19.    FATIGUE                 1                  02-03-83  0-3 SCAL   8-01-79
21.    ARTHRALGIA              0                  02-03-83  0-3 SCAL   9-18-80
36.    MYALGIA                 1                  02-03-83  0-3
 7.  AODM                      POOR               02-03-83  CONTROL    5-27-80
12.  CARDIOMYOPATHY                                                    6-26-80
13.    PREMATURE ATRIAL ARRY   7                  10-09-80  #/MINUTE   6-26-80
20.    PEDAL EDEMA             2+                 02-03-83  0-3 R/L   -
23.    ORTHOPNEA                ?                 01-13-83  0-3       -
28.    LBBB
30.    RALES                   1/0                02-03-83  0-3 L/R
41.  PAIN, ABDOMINAL           3                  02-03-83  0-3        7-02-81
27.    ANTRITIS                 ?ACTIVE           02-03-83  0-3       1-81
42.    BILE GASTRITIS/ESOPH     ?ACTIVE           02-03-83  0-3
45.  PAST MEDICAL HX
 3.    S/P SUP THROMBOPHLEBI   2                  02-03-83  LEG PAIN  APRIL 80

...CONT:
```

Fig. 5.2a SCREEN-31 The probe point, Stewart, appearing in the extreme Upper-Left corner, is shown as an underlined letter.

```
    Desert Community Hospital, Clinical Pathology, Sun City, AZ  80365
Report Time: 04/08/86 1545    VDP TT1967          Route To: FOXLEE,RICHARD MD
------------------------------------------------------------------------------
  Spec. Type: BLOOD
Test Name                   Result Norm Range     Test Name        Result Norm Range

Na  (mEq/l):                  141   136-145       Trig  (mg/dl):     155 * 10-150
K  (mEq/l):                   4.0   3.5-5.0       Ca  (mg/dl):       9.2   8.5-10.5
Cl  (mEq/l):                  106   96-106        Phos  (mg/dl):     3.8   2.5-4.5
CO2  (mEq/l):                  27   24-30         Alk Phos  (U/l):   133 * 30-115
BUN  (mEq/l):                  13   6-26          SGOT  (U/l):        28   0-41
Creat  (mg/dl):               0.8   0.70-1.70     LDH  (U/l):        145   60-200
Tot Prot  (g/dl):             7.3   6.0-8.5       CPK  (U/l):         63   0-225
Album  (g/dl):                4.4   3.0-5.5       (Na+K)-(Cl+CO2):  12.0
T. Bili  (mg/dl):             0.5   0.2-1.2       A/G:               1.5
Dir Bili  (mg/dl):            0.1   0.0-0.4
Gluc  (mg/dl):                 92   70-115
Uric Acid  (mg/dl):           2.7   2.2-2.7
Chol  (mg/dl):                191   140-270


------------------------------------------------------------------------------
Log-in Time: 04/08/86 1428    Fri Apr 08,1986          PARTON, BETTY J
                    SMAC                               1327550 O/P-CLINIC(PHYS)
```

Fig. 5.2b SCREEN-34 The probe point, Parton, appearing in the Lower-Right corner, is shown as an underlined letter.

The results are consistent with those reported in the previous example. The probe in Quadrant 1 yielded an average response time of 3,469 msec., while the probe in Quadrant 4 yielded 8,880 msec. The results are summarized graphically here:

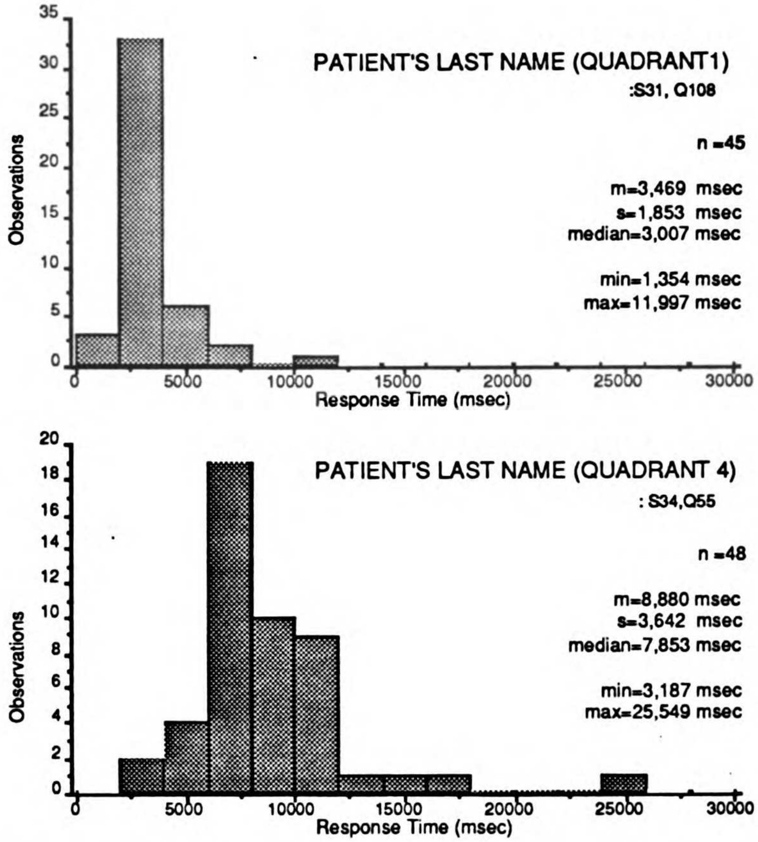

Fig. 5.2c Distribution of Response Times (n4) for "Patient Last Name" found on two different screens in very different locations.

In this example, comparative percentiles remain relatively constant along much their range:

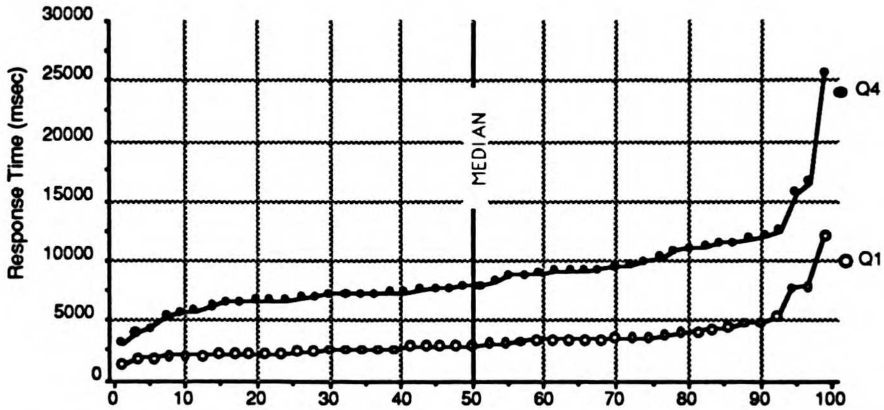

Fig. 5.2d Percentiles of Response Time (n4) for "Patient's Last Name" found in different quadrants.

5.2.3 Some Analysis of the Positional Effect

Observations such as those described above lead to a analysis of the 34 screens used in this experiment as a whole to seek statistical evidence of a Positional Effect.[1] While one can observe a marked deterioration in the behavior of the distributions[2], indeed the same phenomenon appears again:

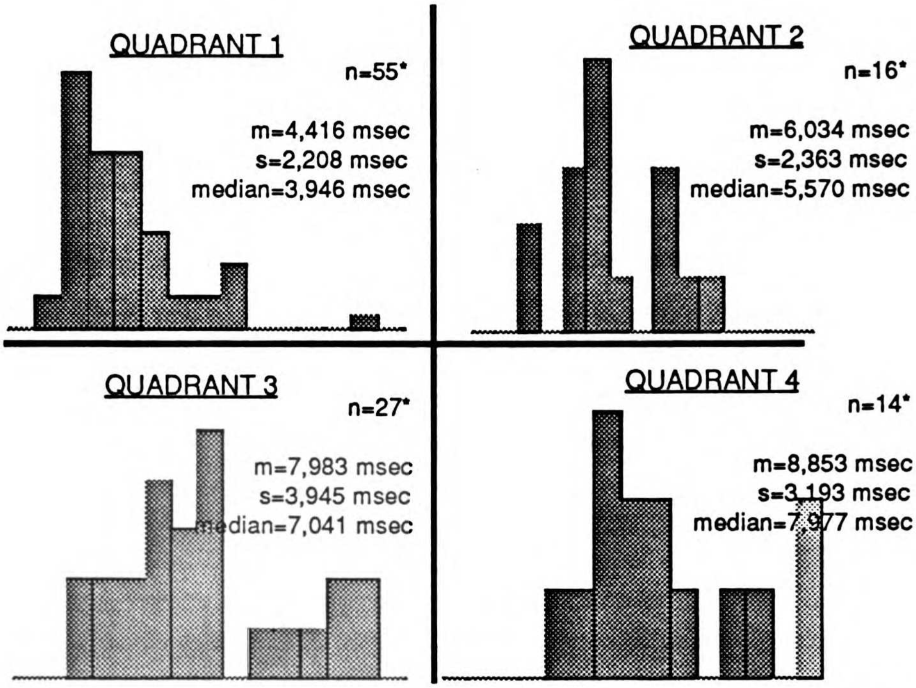

Fig. 5.3a Distribution of Response Times by Quadrant (n4) for ALL 34 screens analyzed in this experiment.

Notice that the median search time increases by roughly one second in each successive quadrant:

1 Median results for each probe were used to produce these summary results for the experiment as a whole.

2 These distributions are not as well-behaved as those presented earlier because they are influenced no doubt by bedeviling semantic factors.

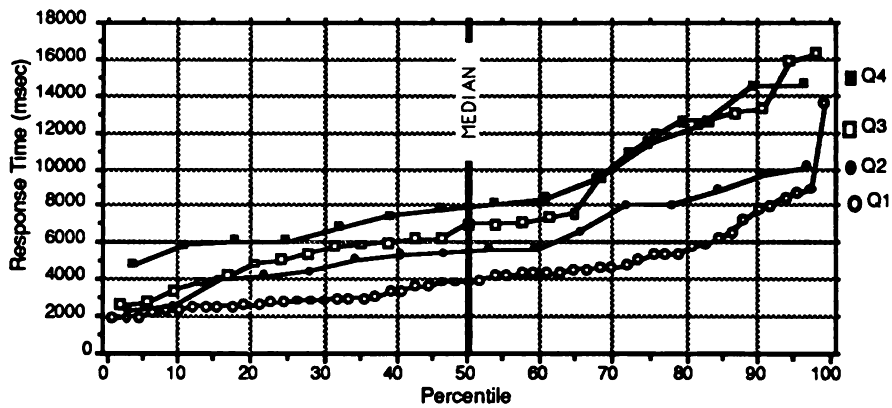

Fig. 5.3b Percentiles of Response Time by Quadrant (n4) for ALL screens.

> *There is a penalty of approximately one second for placing data in subsequent quadrants removed from the upper-left corner of the display.*

	Q1	Q2	Q3
Q2	t= -2.539 p= .0067		
Q3	t= -5.251 p= .0001	t= -1.789 p= .0405	
Q4	t= -6.096 p= .0001	t= -2.771 p= .0049	t= -0.712 p= .24

Fig. 5.3c Results of unpaired t-Tests between quadrants for "Patient's Last Name" example. (n4) Significant results ($p<.01$) are shown unshaded.

As one proceeds across the quadrants (roughly in Quadrant 1 - 2 - 3 - 4 order), human performance in this visual search task rapidly deteriorates. In the experiment, it took roughly twice as long to complete the task for data presented in Quadrant 4 (Lower-Right) as was required in Quadrant 1 (Upper-Left).

Search time may double if items are placed far away from the upper-left corner of the display.

5.3 THE POSITIONAL EFFECT: FASHIONING AN APPROPRIATE MEASURE

5.3.1 Possible Correlates to Response Time and Error-Rate

Possible correlates to Response Time were examined with the goal of identifying one which was statistically compelling, intuitively natural, yet easily computable.

Row position generally dominates column position in influencing Response Time.[1]

Response time is a function of a number of components: Where does one begin searching?[2] What search strategy is used in deciding where next to look? How long does it take to mechanically move one's eyes from the current position to the intended position?[3] Does the first search fail and therefore require one (or more) additional attempts?

One possible hypothesis would suggest that a subject might tend to rest in center screen, the usual point of highest information density. This is clearly not the case for these visual presentations. "Distance from screen center" is a very poor correlate.

Note that the simple correlate, "Quadrant" does well; searches for a datum located in the first quadrant were fastest; searches in the second, third and fourth quadrants were progressively slower.

Although over thirty possible correlates to Error-Rate[4] were tested, none were found. In fact, correlations to Error-Rate are so poor as to be notable.

---

1 This should not be too surprising. Given the aspect ratio of a VDT, there are many more (80) columns than there are rows (24).

2 Kosslyn reports that his results clearly indicate that the ease with which items can be retrieved from an image is a function of actual physical distance from the point of initial focus. [KOSS73]

3 Stark and others have performed many experiments aimed at measuring this speed. [STARK81]

4 Error-Rate is defined here as: 1 – %correct-on-first-try.

R^2	Response Time	Error-rate
Row	.232	.053
Col	.079	.009
Distance from upper-left : (D.U.L. = Row/24+Col/80)	**.284**	.047
Quadrant	**.256**	.029
Distance from screen-center	.067	.031
Log Row	.234	.06
Log Col	.044	.01

Fig. 5.4 Possible Correlates to Response Time and Error-Rate. (n4)
The best correlates are shown in bold.

Of the factors which correlate to Response Time, the factor:

$$\text{Distance from Upper-Left (D.U.L.)} = \frac{\text{Row}}{24} + \frac{\text{Col}}{80}$$

was chosen for further study. This correlate offers several advantages over other possible correlates:

- It is the strongest correlate tested, explaining more than one-fourth of variance in Response Time.

- It is an intuitively natural measure of distance from the Upper-Left corner. It can be easily visualized by a screen designer in the process of design.

- Values range only from zero in the extreme Upper-Left to a value of two in the extreme Lower-Right. The midpoint of the display represents a value of one, as do all positions along an isobar connecting the Upper-Right corner to the Lower-Left corner:

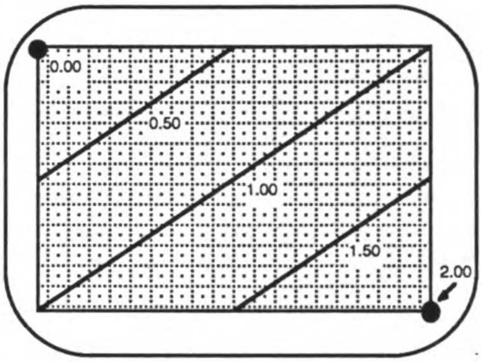

Fig. 5.5 Isobars of D.U.L. (Distance from Upper-Left). Values range from zero to two.

- This model is intuitively compelling since it is the most general and simplest mathematical formulation which describes a movement from Upper-Left toward Lower-Right.
- It is easily computable; it is the simplest mathematical formulation using only two arithmetic operators. It operates only on the variables Row and Column, values which are readily accessible during the design process[1].

5.3.2 The Positional Factor as a Predictor of Response Time

5.3.2.1 A Linear Model

Simple regression was employed to derive a linear equation describing the influence of D.U.L. on Response Time. The resulting equation is:

1 Many screen descriptive languages include "automatic" variables containing current Row and Column values.

Response Time(msec) = 3,006 + 3,952 x D.U.L. (r^2=.284)

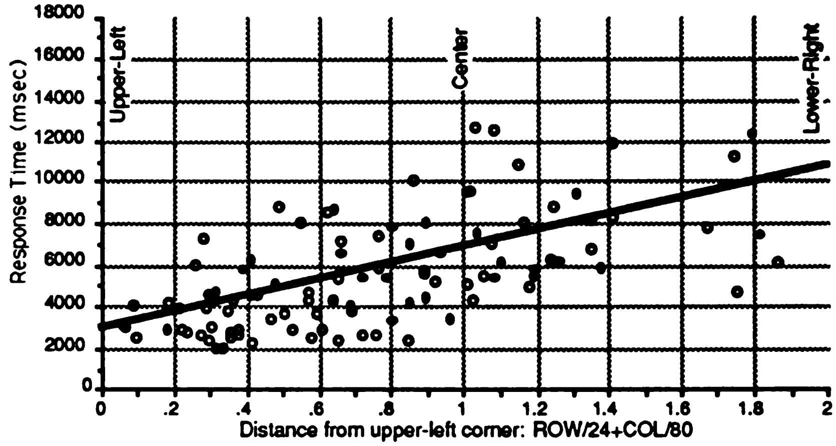

Fig. 5.6 Simple regression – D.U.L. vs. Response Time. (n4)

The slope of this regression equation suggests that there is a potential penalty of nearly eight seconds (2 x 3,952 msec.), which can result, in the most extreme case, when choosing a screen position for a datum. The intercept of the equation suggests that three seconds (3,006 msec.) is a minimum median search time required regardless of data placement.

5.3.2.2 *A second linear model*

Since the factor Quadrant (Q) also performed well, a second linear model was constructed to offer an alternative model. Correlation of Quadrant to Response Time was only slightly poorer than the D.U.L. factor described above.

Response Time(msec) = 2,866 + 1,597 x Q (r^2=.256)

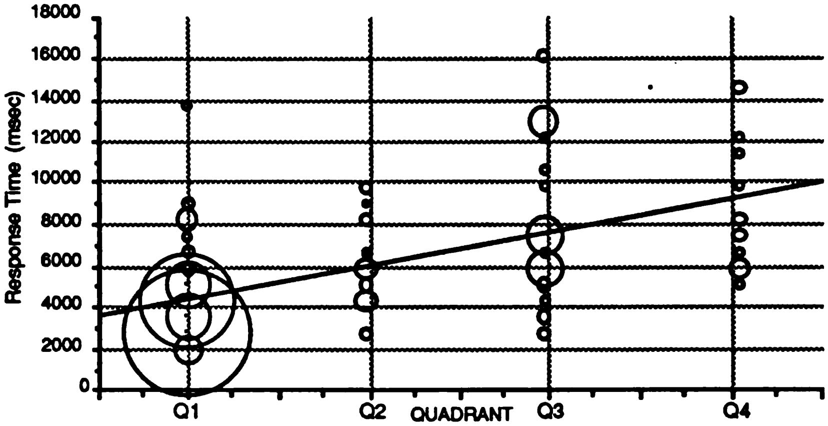

Fig. 5.7 Simple regression – Quadrant (Q) vs. Response Time. (n4)

5.3.2.3 A second-order polynomial model

A second-order regression equation was also derived to fit D.U.L. to Response Time. A slightly better fit can be obtained using the higher-order fit, however the improvement appears mainly at extreme values.

Response Time(msec) = 1,565 + 8,323 x D.U.L. + 2,484 x $(D.U.L.)^2$ (r^2=.282)

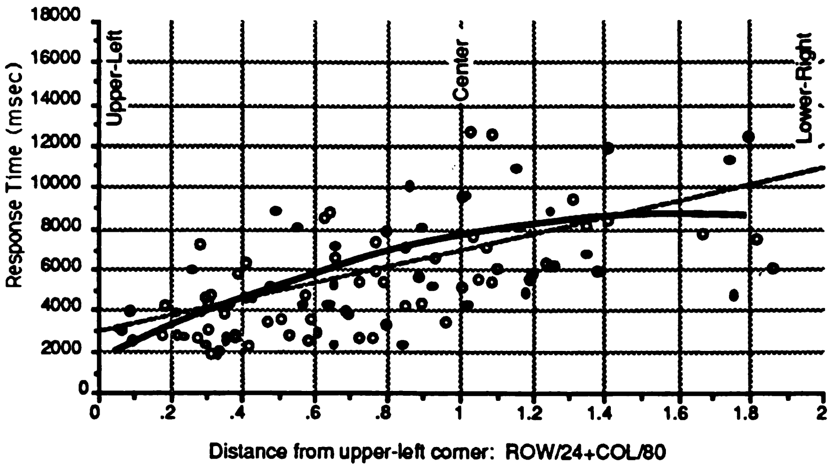

Fig. 5.8 A second-order polynomial equation describing D.U.L. and Response Time. (n4)
(The linear equation is shown for comparison.)

5.3.2.4 *A model using multiple regression.*

Of course the simplest formulation possible would to be involve the factors Row and Column directly. We present the results of a multiple regression on these two factors:

DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
111	.523	.274	.26	2877.422

Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	2977.017				
ROW	210.576	39.024	.447	5.396	.0001
COL	32.769	13.075	.207	2.506	.0137

$$\text{Response-Time(msec)} = 2977 + 210 \times ROW + 32 \times COL$$

Fig. 5.9 Resulting equation from a multiple regression of Row and Column vs. Response Time. (n4)

It is interesting to note that this multiple regression does more poorly than a simple regression on D.U.L. alone. One explanation is that the simpler D.U.L. does consider the aspect ratio reflecting the physical size of each character position.

5.4 SOME IMPLICATIONS OF THE POSITIONAL FACTOR

What are the implications of this result on software psychology? It seems clear from the above analysis that the casual user essentially reads an unfamiliar display. Since reading, in Western culture, requires scanning from left to right, and from top to bottom, we obtain results consistent with those which a reading paradigm would suggest.

This result casts some doubt on humans' ability to do certain parallel processing of visual stimuli. Unlike the octopus in a barnyard experiment[1] [LOFT81], it does not appear here that early visual processing of the input stimuli allow the viewer to short-circuit the scanning process by moving directly to the datum of interest, or even toward a likely area where the datum of interest might be found. Subjects appear to plod along, in a rather predictable fashion, using few short-cuts or complex strategies, until the datum is found.

1 Refer back to section 2.3.

One can derive other potentially useful implications. For example, since "row binding" appears more pronounced than "column binding", the row-oriented prompt would seem preferable to the column-oriented prompt. That is,

PATIENTS NAME	Dennis J. Streveler
ADDRESS	127 Lake Merced Hill
CITY STATE	San Francisco CA 94132

might be preferable to:

PATIENTS NAME	ADDRESS	CITY STATE
Dennis J. Streveler	127 Lake Merced Hill	San Francisco CA 94132

This result is consistent with earlier experiments which have shown that the former prompting orientation and arrangement of menus yields improved human performance. [GALI81 and others]

The results clearly suggest the advantage of placing critical[1] or frequently accessed data items as near to the upper-left corner as is possible. The penalty for ignoring this rule is severe.

5.5 SUMMARY

Evidence has been presented regarding the placement of data items within an unfamiliar screen format. Severe benefits, or penalties, accrue from that placement.

For the casual user, this factor alone describes more than one-quarter of the total variance in search times. It does not describe the error-rate which occurs during that search.

It is likely that as a user becomes familiar with the screen design the effect of position might be dampened, even largely eliminated by memory.[2] However, for the casual or unlearned user, it is hard to overemphasize the performance benefit

1 For example, it may be prudent to place critical and abnormal laboratory results at/near the top of a panel of clinical chemistry results.

2 Anderson terms this human faculty "locational memory". [ANDE80] Norman calls it "selective information retrieval from preset spatial locations in a generative image". [NORM76, p.164]

which can accrue from the placement of important or frequently accessed data at or near the natural reading home position (i.e. in the Upper-Left).

Further studies of learning effects and eye-movement experiments [STAR81 and others] could be performed to strengthen, and to further understand, these results.

6. THE EFFECT OF LOADING

6.1 INTRODUCTION

Perhaps no other factor of screen design has undergone such rigorous scrutiny as has the loading factor. This is the one psychological factor which has consistently received attention from researchers, in an attempt to explain human performance in this area.

Even before the computer era, studies were made of the tactical difficulty of recognizing targets from maps created in wartime. These maps contained varying numbers of targets, or were said to be "loaded"[1] with varying numbers of targets. Studies were aimed at determining just how many targets one could present on a map without degrading the human performance required in searching for a target of interest.

When electronic displays were introduced, it was natural for researchers' attention to focus on the difficulty of spotting new "targets", this time these targets involved locating textual objects displayed on the face of the display tube.

6.2 WHAT IS LOADING?

Intuitively, loading is a simple concept. All VDT users can recognize "busy" screens. The "busier" the screen, the harder it seems to be able to locate a particular datum, especially when performing under stress, or when the screen layout is unfamiliar. It is reasonable to assume that a "busy" display is more difficult to scan, and therefore would require more time, and induce more errors. Is this true?

Before pursuing that question with empirical data from our study, let us examine the concept of loading more rigorously. Indeed there exist many potential definitions of loading.

6.2.1 Global vs. Local loading

First, the notion of global vs. local loading must be addressed. Imagine a screen design in which the second quadrant is completely packed, while the third

1 While an explicit reference can not be located, it would appear that this is how the term "loading" came to be used—a throw-back to a military term used in describing the saturation of targets on a map.

quadrant remained nearly empty[1]. Would it be reasonable to assume that a datum could be located with equal ease in both quadrants? Clearly, no. We would expect a local effect in such an instance due to the discontinuity in loading.

Global loading is the usual subject of investigation, because in most uncontrived design situations, screen layouts are reasonably evenly loaded across the display surface. This is certainly true of the display formats which were selected for use in this study. Since the viewport of an alphanumeric display is small, almost all practical applications require that the entire page be used.

6.2.2 Kinds of loading: pixel, character, field, chunk

Other problems remain with the definition of loading. Creating a definite measure of (global) loading is not straightforward. One could define the measure as the number of illuminated pixels, therefore an uppercase "W" would contribute more to the loading measure than would, say, a lowercase "i". This distinction might be useful if our investigation centered on the sensory ability of the eye to sense and discern the stimuli which results from attending to the specific character. In this research, we concentrate on the cognitive processing required in decoding whole targets, and therefore are not interested in this distinction. We will assume, without explicitly proving, that the time it takes to "understand" a "W" is not significantly different than the time it takes to "understand" an "i".

In the opposite extreme, one could conceivably define loading in terms of the number of words (using the definition of language), or fields (using the terminology of data processing), or chunks (using a notion from cognitive psychology) [MILL56]. However, these definitions would prove troublesome, because it is quite obvious that some words (e.g. "disestablishmentarianism") use considerably more space than do others (e.g. "the"). Some researchers, applying psychological principles of chunking, have seemed to suggest that this factor exists: "(We) have found that search time is approximately proportional to the number of **objects** (emphasis added) present in the display". [WILL69]

This list then spans the gamut from concentrating on early sensory decoding of primitive impulses, to complex cognitive processes involving pattern matching and reading skills.

1 We pick this illustration because we have shown in the preceding chapter that the Positional Effect is similar in the second and third quadrants, thus we need not concern ourselves greatly with the local effect of position.

We choose character loading as our specific measure for several reasons:

1. It allows a comparison of our results with earlier results reported by other investigators.

2. It is easily computable.

3. It does not depend on type style, font or language.

Character loading is defined as the percentage of VDT cells which are not blank. Thus, if the display contains 200 characters (out of the usual 24x80=1,920 cells), we declare the display to have a loading parameter of 200/1920=10.4%.

6.2.3 Psychological Concepts of Loading

The psychological rationale for the study of this factor is compelling. Most psychologists would ascribe to the notion that the human information processor can become overloaded (referred to as *cognitive loading* or as cognitive overload). There is clearly a point at which processing abilities break down, as frustration and stress set in while attempting to decode a complex display. Displays tend to become overloaded as the screen designer is tempted to add more and more information, but "the beneficial effects of more information must be balanced against the possibility of cognitive overload." [DORI72]

Presenting too many stimuli can even cause destructive interaction which can result in a reduction in sensitivity of the viewer. [SPOE82 p.22] Thus *stimulus numerosity* is related to the ease with which subjects are able to discriminate between targets. Since this discrimination of course requires time, one can reasonably assume that when more objects exists it will require more time to search among them. Presenting too many objects can derail the Gestalt mechanisms of organization, since it is no longer possible to easily delineate between objects.

6.3 EARLIER INVESTIGATIONS OF LOADING

Two hypotheses have been tested previously. The first, and more usual, has suggested that human response time degrades linearly as loading is increased (in the domain of practical design limits – perhaps 10% to 50%). An early example of this finding, reported in 1960 by Baker, suggests that "time and error scores increase as a function of an increase in the number of relevant forms on the problem display." [BAKE60, p.60] The next year, Coffey reported that "higher density conditions degraded subject performance." [COFF61, p.93]

The second hypothesis is that human performance exhibits a U-shaped behavior. The proponents would suggest that loading has an optimum value; if a screen is *over*loaded or *under*loaded, performance will degrade.[1] [SHNE84] This hypothesis is premised on the observation of the complex motivational and motor reactions of the human user. This complexity, so the argument proceeds, should suggest that there exists an optimal value for loading. Besides, given this complexity, error rates will increase simply because, according to the theory's proponents "most human errors occur because humans are capable of doing so many different things in many diverse ways." [DHIL86 p.44]

6.4 ANALYSIS OF LOADING

6.4.1 The Loading Effect on Response Time

The 36 screens of this experiment were analyzed. Median loading of these screens is 21%; mean loading is 26%.

Loading accounts for nearly **one-fourth** of the observed variance in the experiment. From our data, response time increases somewhat linearly as the regression line suggests below:

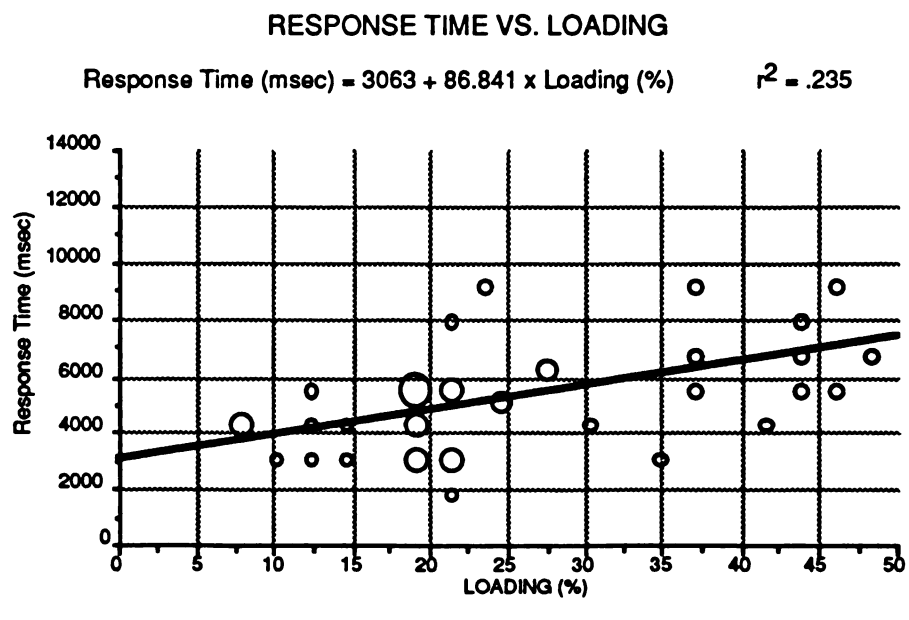

Fig. 6.1 A linear regression showing the relationship of Response Time to Loading. (n4)

1 This may have first been reported by Vity [1966 p.108]: "Both of the curves show that preferences increased up to an intermediate degree and then decreased."

From this analysis, some interesting results can be surmised:

> *A change in loading of 10% adds approximately 1 second (actually 868 msec.) to search time.*

> *To assure that a search will likely take no more than 6 seconds, one must propose a design which is loaded at no more than the 20% level (i.e. no more than 1-in-5 character positions, or no more than 1,344 total character positions be utilized).*[1]

No evidence of a U-shaped effect was found within the limits of Loading which occurred in the experiment (8% for the most sparsely loaded screen tested to 48% to the most densely loaded). Attempts at fitting a regression line of the second or third power were unsuccessful.[2]

> *Earlier suggestions of a U-shaped performance curve could not be substantiated by this experiment. Between the loading limits of 10% to 50% (which are practical limits to screen loading in any case), performance tends to degrade somewhat linearly.*

1 This emphasizes again the very narrow viewport of the typical alphanumeric VDT.

2 It appears that the U-shaped hypothesis has been abandoned by its proponents.

6.4.2 The Loading Effect on Error Rate

The other human performance measure of interest, Error Rate was also analyzed. No effect on Error Rate was observed:

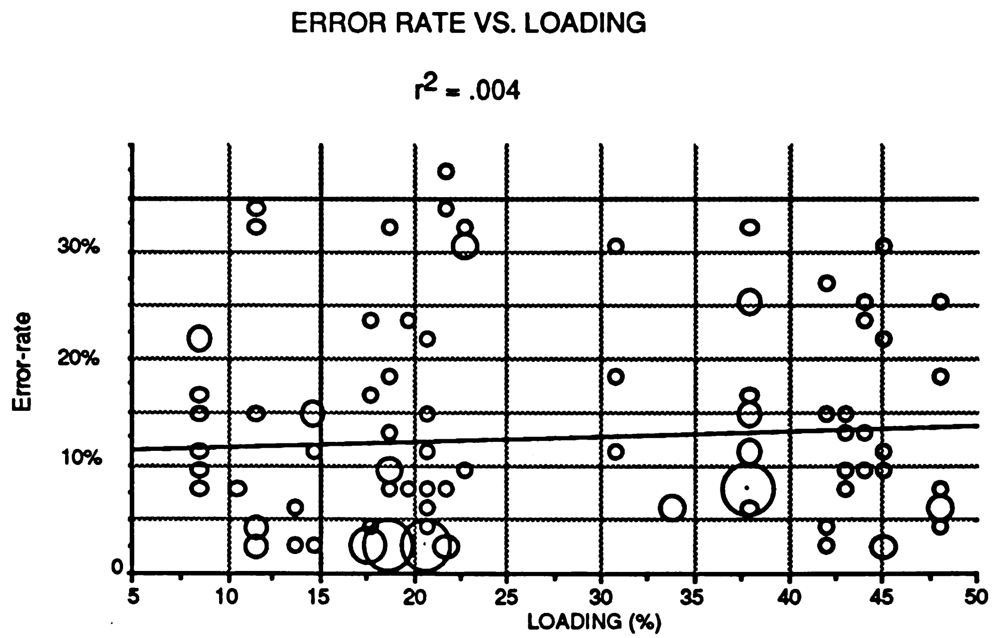

Fig. 6.2 A linear regression showing the relationship of Error Rate to Loading. (n4)

6.5 SUMMARY

Loading has long been a subject of interest to investigators in this area. These experiments tend to strongly confirm the earlier findings that increased loading leads to a somewhat linear degradation of human response time in this visual search task.

No evidence was found to support the U-shape hypothesis.

No evidence was found which indicates that Error Rate increases as Loading is increased.

7. DISCUSSION

7.1 LIMITATIONS OF THIS STUDY

7.1.1 Using Alphanumeric Terminals

The ubiquitous alphanumeric VDT is the host for the screen designs studied in this experiment. The designs were further limited to those which utilize no special video attributes, such as reverse video or blinking or color. Indeed several of them use only an ALL-CAPS character set!

One might argue that this genre of hardware is hopelessly antiquated in our present world of graphic icons, multiple windows, gray scale, and fancy input devices. Why then are the results of this study useful? For two basic reasons:

1. We chose the most primitive environment possible, so as to minimize the temptation to confound the study with unnecessary variables. Information gained from a study of the simple environment will, it is hoped, become a basis upon which studies of newer, more complex environments can begin.

   Might not the primitive factor Position, which is at the center of this study, be generalizable to such questions as:

   a. Where should one place *a graphic icon* so that the casual user is likely to find it most readily?[1]

   b. How should *windows* be arranged?

2. It should be pointed out that the vast majority of today's hospital information systems, laboratory information systems, pharmacy information systems, radiology management information systems, etc. have the alphanumeric VDT as their host.[2]

---

[1] This question is asked rhetorically, since it is not the subject of this investigation. However, one might reasonably predict that it might be just as prudent to put "important" icons near the top-left corner as it is to put the most important textual data.

[2] Nearly 100% of today's systems in fact use a similar VDT. This includes such luminaries as the TDS/Technicon THIS system and the Duke University/PCS/ADS/OMEGA family of hospital information systems, to name just two.

> It is also observed that many of the new clinically-based systems which are being proposed, and whose prototypes are today being built, still largely use textual interfaces. For example, today's rage in clinical systems is the so-called bedside terminal. One such popular terminal has only eight rows and eighty columns, and displays only alphanumeric characters.

Although the demise of the alphanumeric VDT has long been predicted, it is likely to survive for many years to come.

7.1.2 The Effect of Learning

The focus of this study has been the casual user, who has little experience with the application program (and its screen designs). This focus was chosen to more closely model such users as clinicians who casually, and infrequently, access data via computer systems in a hospital, medical group, or other such setting. Such users are discretionary users, since they are usually not compelled to interact with such a system, and in fact have shown considerable resistance to computers when they are made available. [SHORT81]

At the opposite end of this spectrum is the rote user, whose job function constantly involves human-computer interaction with one, or a small set, of computer applications. The application, in this case, is so familiar that one can frequently observe such users accessing the system "heads-down", that is, paying little attention to the screen, and being able to repetitively access target data with little or no scanning. An example of such a user might be an airline reservation clerk.

What happens in between? How does a user become expert? Are the results of this study generalizable to the more expert user?

It is likely that the positional effect would fade, as the repetitive user makes use of other cognitive skills such as locational memory.[1] From our study, we are unable to predict how long the Positional Effect lasts. We do not know how long learned screen positions persist, or when locational memory decays as a user, who had gained familiarity with a screen design, is away from the design for a time.

---

1 Locational memory is a strong cognitive skill. It is frequently demonstrated by having a person recall where an advertisement in a newspaper was seen. Even after a short exposure to the newspaper, the person will be able to recall that a certain ad was in the lower-right hand corner of the the left page. At the same time, the person may not recall the content of the ad, or where in the newspaper the page containing the ad appeared.

The existence of locational memory may explain why "poor" screen design has been tolerated. Apparently, after awhile, you can accommodate almost any scramble of characters if you remember where to look for the data of interest.

7.1.3 The Effect of Semantics

We have chosen to concentrate on an examination of *syntactic* properties of screen design. Clearly *semantic* properties of screen designs must also play a role in an individual's ability to locate data of interest. (If data were presented in an unknown language or symbol set, a subject would not be able to retrieve it regardless of how "well" the screen was designed.)

In the experiment, careful controls were exercised to control for language ability for this reason. Subjects were allowed to practice with the speech synthesizer to minimize any confounding effect it might introduce.

But, regardless of how carefully controls are exercised, more complete models of human performance will need to include the study of semantics. This study is inherently difficult, since proposing computable metrics is a formidable task.

7.1.3.1 An Example: Sorted vs. Unsorted Data

As semantic cues are introduced, cognitive strategy can shift abruptly, as can be demonstrated by the following example. Consider two screen designs which are identical in all respects, save that one presents data in a sorted order while the other does not. The subject is *not* informed ahead of time that the screen being presented is sorted or unsorted, nor is there any explicit information appearing in the design to indicate that data are (un)sorted.

692202-3	LOTT,DOROTHY	08/07/1922	60	F
726754-1	LUTHI,DEBORAH MAE	03/05/1948	35	F
045682-9	LATO,ELVIRA VITTORIA	03/17/1960	23	F
665817-2	LEDDY,ELIZABETH	11/25/1931	51	F
014018-0	LLOYD,EUGENIA	03/01/1930	53	F
480706-5	LLOYD,EILEEN ISABELLE	08/01/1933	49	F
596394-0	LOTT,ELLA WEASE	07/03/1927	55	F
594925-4	LUHT,EILEEN	08/13/1915	67	F
799338-2	LADIA,FELECISIMA YABOT	08/12/1916	66	F
213606-6	LLOYD,FERMER	12/12/1910	72	F
428806-2	LLOYD,FRANCES ELLSWORTH	02/24/1900	73	F
853664-3	LLOYD,FRANCEEN	01/03/1949	34	F
783472-1	LADD,GRACE BEULAH	06/21/1902	70	F
512186-8	LEDDY,GENEVIEVE V	12/21/1897	79	F
618304-2	LLOYD,GRACE V	08/20/1898	84	F
803531-8	LEETE,GLADYS	11/10/1902	50	F
350935-4	LLOYD,GISELA RITA	07/04/1933	49	F
429025-4	LLOYD,HAZEL	04/22/1907	76	F
798330-1	LLOYD,GLORIA DEAN	01/28/1945	38	F
878846-4	LLOYD,GAIL LYNN	12/07/1951	31	F
709939-4	LOYD,GWENDOLYN ANN	04/09/1948	35	F
697963-7	LEDAY,HAZEL	04/14/1916	67	F
574910-1	LEITE-AH YO,HARVELEE	07/03/1953	29	F

Fig. 7.1a SCREEN-32 An example from a hospital information system showing an unsorted list of patients, along with certain demographic information. The probe point is underlined.

Subjects were asked to locate the "Age of Grace Lloyd" in this unsorted list of patients. The mean Response Time for the screen above was 9,733 msec.

Now consider this design which presents a sorted list of (the same) patients:

799338-2	LADIA,FELECISIMA YABOT	08/12/1916	66	F
783472-1	LADD,GRACE BEULAH	06/21/1902	70	F
045682-9	LATO,ELVIRA VITTORIA	03/17/1960	23	F
697963-7	LEDAY,HAZEL	04/14/1916	67	F
665817-2	LEDDY,ELIZABETH	11/25/1931	51	F
512186-8	LEDDY,GENEVIEVE V	12/21/1897	95	F
803531-8	LEETE,GLADYS	11/10/1902	79	F
574910-1	LEITE-AH YO,HARVELEE	07/03/1953	29	F
480706-5	LLOYD,EILEEN ISABELLE	08/01/1933	49	F
014018-0	LLOYD,EUGENIA	03/01/1930	53	F
213606-6	LLOYD,FERMER	12/12/1910	72	F
853664-3	LLOYD,FRANCEEN	01/03/1949	34	F
428806-2	LLOYD,FRANCES ELLSWORTH	02/24/1900	71	F
350935-4	LLOYD,GISELA RITA	07/04/1933	49	F
618304-2	LLOYD,GRACE V	08/20/1898	84	F
798330-1	LLOYD,GLORIA DEAN	01/28/1945	38	F
878846-4	LLOYD,GAIL LYNN	12/07/1951	31	F
429025-4	LLOYD,HAZEL	04/22/1907	76	F
692202-3	LOTT,DOROTHY	08/07/1922	60	F
596394-0	LOTT,ELLA WEASE	07/03/1927	55	F
709939-4	LOYD,GWENDOLYN ANN	04/09/1948	35	F
594925-4	LUHT,EILEEN	08/13/1915	67	F
726754-1	LUTHI,DEBORAH MAE	03/05/1948	35	F

Fig. 7.1b SCREEN-33 An example from a hospital information system showing an sorted list of patients, along with certain demographic information. The probe point is underlined.

Subjects who were asked to locate the "Age of Grace Lloyd" in this sorted[1] list of patients did considerably better. Their mean Response Time was 6,803 msec. or more than 30% faster than those who were faced with the task of retrieving this information from the unsorted list.[2]

The Error Rate for those subjects who were forced to navigate an unsorted screen was considerably higher (15.5%) than was their counterparts who were provided the additional implicit semantic cue (10.0%).

Here is a summary of these results:

1 Note that the terms "unsorted" and "sorted" are used to indicate relative degree of sorting. In the first example, the "unsorted" display can be considered "partially sorted" or "bucket sorted". The second example, while still not completely alphabetically sorted, is clearly "more partially sorted" than the first.

2 It should be noted that in this demonstration the syntactic properties of the two screens were held constant, and that the probe point in both cases occurs at exactly the same position.

DATA ARE:	RESPONSE TIME	ERROR RATE
UNSORTED	9,733 msec.	15.3%
SORTED	6,303 msec.	10.0%

7.1.4 The Effect of Other Syntactic Factors

Besides Position and Loading, there may exist other syntactic factors which could also predict human performance in this task. In the experiment, a number of hypotheses were tested to attempt to uncover more factors. We have limited this report to a study of two factors, one newly discovered, one corroborating earlier investigations, which have clear statistical significance.

From the experiment, some evidence appears that there are indeed other syntactic properties which are at work. Here is an example of one such factor, Alignment, which while we cannot produce compelling conclusions, would tend to provide some evidence of the existence of this factor.

7.1.4.1 An Example: An Additional Alignment Cue

Consider the following two screen designs which are very similar, except for an additional Alignment cue which is present in the second design example:

PRESENT SITUATION		GMT 1102:15
LAT		LONG
38 17'42"N		94 52'06"W
WIND	DRIFT	COURSE
292/146	1° L	281
G/S	TAS	TK ERROR
299	348	1° R
AVG WF		XTK ERROR
-100		0.5 L NM
OAT	TEMP D	A/C GROSS WT
-49	7+	408364 LBS

Fig. 7.2a SCREEN-18 An example from NASA-Ames Research Center. The probe points are underlined.

Four data items were probed: Latitude, Drift, Gross Weight, and Temperature. Here is a summary of results for this screen design, which provides minimal alignment cues:

QUESTION ASKED:	RESPONSE TIME	ERROR RATE
LATITUDE	3,203 msec.	9.3%
DRIFT	5,528 msec.	16.0%
GROSS WEIGHT	7,570 msec.	22.4%
TEMPERATURE	7,368 msec.	14.8%

Now consider a slightly modified screen design, which purportedly provides additional alignment cues. (Note how the data appears in slightly offset columns, separating it visually from the title fields.)

```
PRESENT SITUATION                          GMT  8:24:15

LAT                                        LONG

 61 07'31"N                                 26 18'33"E

WIND              DRIFT                    COURSE

 187/116           3° R                     021

G/S               TAS                      TK  ERROR

 487               530                      4° L

AVG WF                                     XTK ERROR

 -241                                       0.5 L NM

OAT               TEMP D                   A/C GROSS WT

 -79               16+                      217262 LBS
```

Fig. 7.2b SCREEN-35 A slightly modified version which provides additional alignment cues. The probe points are <u>underlined</u>.

Here are the results of the same four probe points which appeared in the earlier example:

QUESTION ASKED:	RESPONSE TIME	ERROR RATE
LATITUDE	2,820 msec.	0.0%
DRIFT	4,791 msec.	11.1%
GROSS WEIGHT	8,189 msec.	21.3%
TEMPERATURE	6,648 msec.	8.0%

Notice that in three of the four results, the Response Time decreases as even a minimal additional Alignment cue is introduced. In all four results, the Error Rate decreases. These results might suggest the existence of an Alignment factor.

7.2 OPPORTUNITIES FOR FURTHER RESEARCH

Ample opportunity to extend this field of inquiry clearly exists. Such an extension of this inquiry might include:

- An examination of more complex VDT technologies, which incorporate video attributes, color, graphic icons, multiple windows.

- An examination of other syntactic properties such as Alignment, Clustering, Grouping, etc.

- An examination of the learning effect and the time it takes for the Positional Effect to decay as a user becomes familiar with an application.

- An examination of the cognitive strategies used in scanning a VDT display (using eye movement equipment or other such apparatus).

Opportunities also exist to extend this research toward the creation of software tools such as:

- An engine which evaluates a proposed design and predict human performance for various classes of users.

- A screen-designing expert system which designs its own screens from high-level representations of the data dependencies of the items which are to appear.

8. CONCLUSION

8.1 SUMMARY OF RESULTS

Presented here is a summary of definitions and results from the experiment.

8.1.1 The Dependent Variables

In our experiment we considered two dependent variables, Response Time and Error Rate.

EVENT:	IS DEFINED AS:
A RESPONSE	The time required for an untrained subject to locate a datum of interest on the face of a VDT display.
AN ERROR	The subject either answers incorrectly (i.e. depresses an incorrect key), elects to skip the question (it will be recycled randomly later), or a timeout occurs (twenty seconds elapse with no key being depressed).

DEPENDENT VARIABLE:	IS DEFINED AS:
RESPONSE TIME	Response time (measured in msec.) is the elapsed time between the moment the screen is presented and the moment the first press of a key on the keyboard occurs.
ERROR RATE	Error Rate is the ratio of "errors" to the total number of trials presented to a subject.

8.1.2 Descriptive Analysis Summary

We found that it takes a considerable amount of time for a subject to perform the visual search task, and that the typical Error Rate for a subject was high:

DEPENDENT VARIABLE:	FINDINGS FOR ALL SUBJECTS:
RESPONSE TIME	A subject on average required 6,737 msec. to answer a question **correctly**. A subject on average required 11,283 msec. to answer a question **incorrectly**.
ERROR RATE	The average Error Rate of subjects was 25.1%.
RESPONSE TIME vs. ERROR RATE	Error Rate and Response Time are correlated. The longer a question takes to complete, the more likely an error will be committed.

8.1.3 The Positional Effect

We have demonstrated the existence of a Positional Effect using both within-screens and between-screens examples, and through an analysis of all screens tested in this experiment.

RESULT:	CONCLUSION:
A measure of the Positional Effect (D.U.L.=distance from upper-left) can explain approximately one-fourth of the variance of Response Time which was observed in this experiment.	Position is a potent factor in predicting human performance among casual users.

There is a penalty of approximately **one** second for placing data in quadrant Q2 rather than in quadrant Q1 (the upper-leftmost). There is a penalty of approximately **four** seconds for placing data in quadrant Q4 (the lower-rightmost) rather than in quadrant Q1 (the upper-leftmost). Search time may **double** if items are placed far away from the upper-left corner of the display.	Significant penalties will accrue if a datum, which must be retrieved frequently, or whose accuracy is particularly crucial, is placed far from the upper-left hand corner of the display.
Error Rate was not found to be correlated to any measure of the Position tested.	Although a correlation between Response Time and Error Rate is reported, and between several measures of the Position and Response Time, no correlation is reported between Error Rate and Position.

8.1.4 The Effect of (Global Character) Loading

This experiment corroborates most of the findings of earlier investigations into this factor. The Effect of Loading can explain approximately one-fourth of the observed variance of Response Time.

RESULT:	REMARKS:
A change in loading of 10% adds approximately one second to Response Time.	Response Time degenerates rapidly as a screen design becomes "crowded".
No evidence of a U-shaped performance variable was found	This effect had been hypothesized by earlier investigators, but never substantiated.

No evidence of a Loading Effect on Error Rate was observed.	Error Rate appears to be more likely correlated to "semantic" factors (i.e. a "difficult question" will elicit more errors) than to "syntactic" factors, such as those studied here.

8.2 A CLOSING PERSPECTIVE

Throughout man's experience with the computer, his most complex tool, the human-computer interface has been allowed to evolve in an undisciplined way. The interface is the fragile link through which man will increasingly communicate with data from his environment.

We can only hope that, as we assign new responsibilities to the tool – tasks which deal with our financial security, our health, the exploration of space, even our strategic nuclear defense — that we will venture to understand more fully the nature of the interface, so as to optimize our performance in interacting with our invention.

This work has attempted to make one small step in that direction.■

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APPENDIX 1:

EXPERIMENTAL MATERIALS
Instructions to Subjects

Each subject was given explicit instruction regarding the procedures for the experiment. Included here is a copy of the actual instructions which were presented to each subject.

EXPERIMENT INSTRUCTIONS

This is an experiment about screen design. By participating in this study, you can help us determine whether you are able to more rapidly and accurately locate items of interest from some screens than from others. You will be presented with approximately 60 screens. The same screen may appear more than once. The experiment will take about 30 minutes or so.

You will be asked to visually locate one item on the screen, and to type the FIRST CHARACTER of that item.

➡ Do you understand?

More specifically, this is what will happen. For each screen:

1. The voice will ask "Are you ready?". Don't hurry. Relax. You may pause as long as you wish between trials. When you are ready, press the space-bar.

2. The voice will then ask you a short question, for example, "CITY".

   IMPORTANT: If you do not understand the question, quickly press the space bar again and the question will be repeated. You may do this more than once if it is necessary.

   MAKE SURE YOU UNDERSTAND THE QUESTION BEFORE CONTINUING!

3. After a few moments, a screen will be presented to you on the video terminal.

4. Locate the item requested by the voice. Quickly type in the FIRST CHARACTER of that item.

   For example,

   If CITY was SAN FRANCISCO, type in "S" or "s" (either will do).
   If DATE was 04/12/83, type in a "0" (zero).
   If FIRST NAME was MARTIN, JOHN H then type in "J" or "j".

   Accuracy is important, so don't type in an answer until you are sure your answer is correct.

   IMPORTANT: If you cannot determine the answer, you may skip this question pressing the space bar at this point. The question may be asked again later.

5. When you press any key, the screen will immediately go blank. The voice will tell you if your answer was correct by saying "correct". A question answered incorrectly may reappear later.

6. There will be a brief pause. Then the next trial will begin. (Goto #1.)

➡ Do you have any questions?

THANK YOU FOR PARTICIPATING IN THIS EXPERIMENT!

APPENDIX 2:

EXPERIMENTAL MATERIALS
Subjects' Questionnaire

Each subject was screened through the use of the following questionnaire. Information regarding the subject's typing skills, language proficiency, and computer literacy was considered in choosing subjects.

SUBJECT QUESTIONNAIRE

[illegible]

6:20 PM

Set	4
Subject #	[illegible]
Identifier	[illegible]

SUBJECT QUESTIONNAIRE

INTRODUCTION

Thank you for agreeing to participate in this exercise. Through this research we hope to improve the standard of computer system design in one important area, the area of visual design.

In order to insure this experiment's validity, we must ask certain information about you. Include among the questions are several asking you to appraise your own ability level in various areas on a scale from one to ten. A one indicates "poor" ability. A five indicates an "about average" ability. A ten indicates an "expert" ability, and so on. By "ability" we mean "how good are you at ...", not necessarily how much experience you have in the area.

Please answer the questions completely and honestly. Thank you!

DEMOGRAPHIC INFORMATION

Name (last name first): [illegible] Sex: F Age: [illegible]

Current address: [illegible] Phone (evening): [illegible]

Major (if any): Lib Arts Do you plan to major in Computer Science? yes

Class standing (fr, soph, etc): Sr[illegible]

COMPUTER SCIENCE SKILLS

Nbr of high school computer courses taken: [illegible]

Nbr of college-level computer courses taken (include any you are presently taking): 4

Approximate nbr of computer programs you have ever written: [illegible]

How long ago did you write your first program? (months or years): 1 [illegible]

Please rank your own ability in computer programming: (1 to 10) [illegible]

MATH SKILLS

Please rank your own ability in mathematics: (1 to 10) [illegible]

SUBJECT QUESTIONNAIRE

TYPING SKILLS

How well can you type? Please rank your own ability in typing: (1 to 10) 4

LANGUAGE SKILLS

Is English your native language? (if not, which language) : yes

Do you normally converse at home in English? yes

Do you normally think in English? yes

Do you normally dream in English? yes

Do you speak any language other than English which you did not learn in school? no Which? ______

Please rank your own ability in reading comprehension: (1 to 10) 7

Please rank your own ability in verbal communication: (1 to 10) 7

EXTRA CREDIT

In order to insure that extra credit is applied properly, please tell what course you are currently taking, including section, instructor: ICS 167 (1) Sam Rinoadie Posting # 115

COMMENTS / SUGGESTIONS (fill in AFTER participating in experiment)

As a result of your experience participating in this experiment, are there any comments or suggestions you have for improving the experiment? Was it too difficult? Too easy? Too long? Could you understand the voice synthesizer? Did you get tired? Were you nervous? -- Please share with us any reactions you might have.

I could understand the voice synthesizer, sometimes it seemed to go too slow, like waiting to hear the voice. Was not nervous. I'm fascinated by the experiment.

Thank you again for helping with this experiment. You have been a great help. Best of luck in your studies and in your future career!

[signature]

APPENDIX 3:

EXPERIMENTAL MATERIALS
Screens Used in the Experiment and Summary of Experimental Results

Each screen and screen/question pair used in the experiment is presented here. Accompanying the screen layouts is a summary of experimental results obtained in the experiment: the mean Response Time (n4) and the cumulative Error Rate for each.

Some of the screens, as noted in the appendix, are copyrighted. Acknowledgement of that copyright is provided. These materials are presented under the 'fair use exemption' of the U.S. copyright laws which allows the presentation of facsimiles of certain copyrighted materials when used for scholarly research purposes.

SCREEN NUMBER 1 (AID2.SCN)

```
                                                        File:  student-grades

                         INTERACTIVE DATABASE DESIGN AID
                                    MAIN MENU

              1) LIST ALL TABLES in this database
              2) DISPLAY TABLE definition
              3) DISPLAY DOMAINS in this database
              4) CREATE a new DOMAIN
              5) CREATE a new TABLE
              6) MODIFY an existing TABLE
              7) QUIT

      HELP available on tables, key attributes, domains, and normalization

          Please select (1-7 or H for help)
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
1. ENTER THIS TO LIST ALL TABLES	"1"	48	4935 msec.	15.5%
2. ENTER THIS TO QUIT	"7"	46	3733 msec.	14.8%
58. FILE NAME	"S"	45	5393 msec.	2.2%
59. ENTER THIS TO CREATE A NEW TABLE	"5"	45	5906 msec.	11.5%

This software serves as a design aid for the computer-assisted generation of decision tables to be used in the manipulation of a relational database.

SCREEN NUMBER 2 (BURPRE1.SCN)

```
            P R E - A D M I S S I O N - P E R S O N A L   D A T A
 PATIENT-ID PATIENT NAME           ADDITIONAL NAME TTL  SEX AGE  ADM.DATE TIME
>   403254<>BYERS MARTHA R         <>GRAYSON     <>MRS <>F<>24Y<>07-29---<>1400<
 PATIENT ADDRESS                                     CITY/STATE           ZIP
>1901 SOUTH BOULEVARD "          <>APT 3A        <>CHARLOTTE, N C      <>28209<
 HOME-PHONE    BIRTH-DATE  BIRTHPLACE           REL/CHURCH
>704-535-4163< >8-31-53 < >WILMINGTON N C    < >METHODIST              <
 ROOM-BD   FC    CR  RACE  M/S NOTABLE   SVC   DR-CD  DOCTOR NAME
>       < >02<  >  < > <   >M<  >4<     >SUR< >16025< BROWN J C
HIST# >K36752    <  PREV-ADM >03-75   < SSN >841-88-3141 < SG-DTS
EST-DAYS >   < DIAGNOSIS >POSSIBLE CHOLECYSTOLITHIASIS                     <
REMARKS>NOTIFY DR BROWN WHEN PATIENT ARRIVES                                  <
 OCCUPATION    EMPLOYER NAME/ADDRESS                                TELEPHONE
>SECRETARY   < >APEX BUILDING SUPPIES                          <>    643-1641<
 RESPONSIBLE PARTY          RELATION    TELEPHONE
>BYERS MARTHA R           < >SELF     < >704-535-4163<
 RESPONSIBLE PARTY ADDRESS                           CITY/STATE           ZIP
>1901 SOUTH BOULEVARD            <>APT 3A        <>CHARLOTTE, N C      <>28209<
POSTN>SECRETARY   <EMP NM/ADDR>APEX BUILDING SUPPLIES                         <
 EMERGENCY CONTACT NAME     RELATION    EMERG CONT CITY/STATE       TELEPHONE
>ROBERT E BYERS           < >HUSBAND  < >CHARLOTTE, N C            <>    347-6770<
 INS?
 >Y<
                                                                        Page 1
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
3. PATIENT'S FIRST NAME	"M"	48	4969 msec.	3.9%
5. BIRTHPLACE	"W"	48	9242 msec.	7.4%
60. PATIENT'S LAST NAME	"B"	45	4413 msec.	6.3%
62. HUSBAND'S FIRST NAME	"R"	43	17428 msec.	18.3%

This is the Patient Pre-Admission screen from the Burroughs Hospital Information System (BHIS). Patient names and other demographic data have been altered to assure patient confidentiality.

SCREEN NUMBER 3   (BURSUR1.SCN)

```
                S U R G E R Y   S C H E D U L I N G
     DATE    O/R  START/STOP  ROOM/BED SURGEON NUMBER/NAME          CALL-INIT
WED >08-01<>5    <>0900<>1120<>    160A <>16025< GARDNER R J            >CGH<
PATIENT ID   PATIENT NAME             ADDL NAME    TITLE AGE SEX ADM-DT  OUTPT?
>  426813-9<>SMITH PRISCILLA R      <>MARTIN      <>MRS<>32Y<>F<>07-28<   > <
DIAGNOSIS                                         SPECIAL INSTRUMENT
>APPENDICITIS                                   <>  <
INFO: >                                                                    <
OPER ONE >APPENDECTOMY                                                 <
OPER TWO >                                                             <
ANESTHESIA STAND-BY ANESTHESIOLOGIST                  POST DATE  FS XRAY-EQP FILM
>GENERAL   <  >N<   >56789<BAKER C B                 >JRC<>07-31<> <  > <    > <
SP INSTRUCTION>                                                            <
BLOOD PRODUCTS>      <  BLOOD TYPE >A-<
              >      <
STANDARD PREPS>      <
              >      <
ADDRESS
>50 COMMONS DRIVE                <>APT 35          <>WORCESTER MASS      <>02319<
HOME PHONE     ADDL PHONE      ADM DOCTOR NUMBER/NAME         ACCOM   BIRTH-DATE
>617-842-1209<>617-666-2951<  >16025<BROWN J C               >PRVT< >08-31-53<
RESPONSIBLE PARTY          TELEPHONE     REL INFO
>SMITH JOHN J            <>617-282-1435<    >C<
REMRKS>CALL DR BROWN WHEN PATIENT ARRIVES                                  <
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
7. DIAGNOSIS	"A"	48	6787 msec.	7.7%%
63. PATIENT'S IDENTIFIER	"4"	45	7657 msec.	0%
64. BLOOD TYPE	"A"	45	7976 msec.	7.8%

This is the Surgery Scheduling screen from the Burroughs Hospital Information System (BHIS). Patient names and other demographic data have been altered to assure patient confidentiality. Copyright, Burroughs Corporation, 1985.

SCREEN NUMBER 4 (CIS1.SCN)

```
..............................
.        Welcome to          .
.  The Electronic Mall (tm)  .
..............................

Software              Page 427

******************************
*      S O F T W A R E       *
*        C A T A L O G       *
******************************

   SELECT TYPE OF COMPUTER:

 A. Sony          K. Epson
 B. IBM           L. Televideo
 C. Kaypro        M. Atari
 D. Xerox         N. Superbrain
 E. DEC           O. Vector
 F. H-P           P. TI
 G. Heath         Q. Wang
 H. Osborne       R. Radio Shack
 I. Dyna Byte     S. Apple
 J. Sanyo         T. NEC
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
8. ENTER THIS FOR AN APPLE COMPUTER	"S"	48	6556 msec.	2.0%
65. ENTER THIS FOR AN IBM COMPUTER	"B"	45	4755 msec.	0%

This is a screen designed as the main menu for an online shopping service. Consumers can order computer equipment via this service. Copyright, The Electronic Mall, 1984.

SCREEN NUMBER 5 (CIS2.SCN)

```
CompuServe SIG Special Interest Group
Database Access

Valid commands:
PUB - retrieve from Public ACCESS
NOR - normal SIG access
XA  - Change to new FILE
S   - Scan
BRO - browse thru files
R   - read a file
DOW - download a file
UPL - upload a file
SUB - submit a file
KEY - search keyword list
ERA - erase a file
EXI - exit from ACCESS
UST - list users in SIG
SEN - send message to user
SET - set menu & brief on/off
HEL - explains ACCESS
OFF - logs you off

? xxx   - explain command xxx
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
9. ENTER THIS TO CHANGE TO A NEW FILE	"X"	48	5287 msec.	7.7%
66. ENTER THIS TO EXPLAIN ACCESS	"H"	44	7842 msec.	12.5%

This is a screen designed as a sub-menu for an online forum service. Consumers can exchange messages on a wide range of topics via this service. Copyright, CompuServe, 1983.

SCREEN NUMBER 6 (CIS3.SCN)

```
OAGEE                     PAGE OAG-1

  OFFICIAL AIRLINE GUIDE EE

WELCOME TO THE OFFICIAL AIRLINE GUIDE
(OAG), COPYRIGHT 1983, OFFICIAL AIRLINE
GUIDES, INC., OAK BROOK, ILLINOIS 60521

FARES IN US DOLLARS           MON-04 JUL
SELECTED FOR  SF - LA

#  ONE-WAY  RND-TRP AIRLINE/CLS FARECODE
 NO LOWER FARES IN CATEGORY
1    49.00    98.00    PS/V     V
2*   59.00    89.00    AC/Q     QL
3*            99.00    WA/B     BE77
4*   67.00   122.00    UA/Q     QSASU
5*           118.00    WA/B     BE77
6    75.00   150.00    PS/K     K
7   105.00   210.00    UA/Y     QH
8*           190.00    UA/B     BE70
 * ENTER L# TO VIEW LIMITATIONS
ENTER +,L#,X#,S#,R#,M,RF(#=LINE NUMBER)
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
10. DESTINATION CITY	"L"	36	10652 msec.	30.1%
11. HIGHEST ROUND-TRIP AIRFARE	"2"	48	8872 msec.	30.8%
67. LOWEST ONE-WAY AIRFARE	"4"	43	7901 msec.	22.7%
68. AIRLINE OFFERING THE LOWEST ROUND-TRIP AIRFARE	"A"	29	13912 msec.	32.4%

This screen provides information regarding airline fares available on a certain route (in this example for the route SFO-LAX). It is used by travel agents and consumers who can book airline travel via this online service. Copyright, Official Airline Guide, 1983.

SCREEN NUMBER 7   (COSTAR2.SCN)

```
                              TRANSACTIONS
RANDOLPH,JOHN        1/28/78  1/15/78  DOCTOR: WARREN,MARK,MD
  PRI DX: HISTORY AND PHYSICAL   ENC# 2
#2   DB  ABAQ2  INTERMEDIATE OFFICE VISIT  25.00 BSMA(1)    SUS
#3   DB  WPAN1  ELECTROCARDIOGRAM  15.00  BSMA(1)  SUS
#4   DB  MNBN3  HEMATOCRIT  3.50  BSMA(1)   SUS
RANDOPH,PAULA         2/28/78  2/25/78  PROV: WARREN,JOHN,MD
  PRI DX: PHARYNGITIS  ENC# 2
#6   DB  ABAH1  SHORT OFFICE VISIT  15.00  BSMA(1)   SUS
#7   DB  PNJF3  THROAT CULTURE  15.00  BSMA(1)   SUS
#8   DB  MNDJ1  WHITE BLOOD CELL COUNT  8.00  BSMA(1)    SUS
RANDOLPH,JOHN        1/29/78  3/20/78
#10  CR  AGBE1  BLUE SHIELD PAYMENT  46.50  BSMA()
#11  CR  AFBB1  BLUE SHIELD ADJUSTMENT  5.50  BSMA()
RANDOLPH,JOHN        1/29/78  3/20/78
#13  TR  AHAQ6  TRANSFER TO GUARANTOR  25.00  BSMA()

ACCOUNT INQUIRY OPTION >
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
12. PATIENT'S LAST NAME	"R"	48	2993 msec.	0%
13. AMOUNT OF ADJUSTMENT	"5"	29	15273 msec.	18.4%
69. DOCTOR'S LAST NAME	"W"	45	4162 msec.	10.0%
70. AMOUNT OF PAYMENT	"4"	55	16758 msec.	31.2%

This is a screen from COSTAR, a pioneering effort in automating the entry and retrieval of clinical ambulatory data organized in a problem-oriented manner. Later medical computing projects involving POMR data have borrowed heavily from this design. It was designed at Mass. General Hospital and at MIT in the late 1960's. No copyright notice evident.

SCREEN NUMBER 8 (COSTAR3.SCN)

MAR 1, 1978 PAGE: 1

WILMINGTON MEDICAL GROUP
REVENUE ANALYSIS REPORT
DETAIL FOR PRACTICE

PROFESSIONAL SERVICES

CODE	DESCRIPTION	STD FEE	MONTH-TO-DATE NUMBER	MONTH-TO-DATE AMOUNT	YEAR-TO-DATE NUMBER	YEAR-TO-DATE AMOUNT
BXSJ3	NEWBORN VISIT (HOSP),INITIAL	50.00	30	1500.00	696	30846.30
BXTK2	NEWBORN VISIT (HOSP),SUBSEQUENT	25.00	61	1525.00	769	19246.00
BACS5	COMPREHENSIVE OFFICE EXAM.	45.00	33	1485.00	418	18844.00
BXGL7	FOLLOW-UP EXAM,BRIEF	15.00	66	990.00	959	15107.76
CADF2	FOLLOW-UP EXAM,INTERMEDIATE	25.00	61	1525.00	769	19244.00
AJKX1	FOLLOW-UP EXAM,EXTENDED	30.00	45	1350.00	583	17494.00
DMMP4	COMPLETE RE-EXAMINATION	35.00	24	840.00	456	15964.89
XTST2	COMPREHENSIVE HOME EXAM.	50.00	34	1700.00	419	19994.00
PSCB1	FOLLOW UP EXAM.,INTERMEDIATE	20.00	45	900.00	649	12994.00
QSTU2	COMPREHENSIVE HOSPITAL CARE	90.00	34	3473.63	592	15054.29
			433	15289.63	6310	205789.24

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
14. TOTAL INCOME THIS YEAR	"2"	48	12930 msec.	14.5%
71. COST OF BRIEF EXAMINATION	"1"	44	13407 msec.	11.3%

This is a screen from COSTAR, a pioneering effort in automating the entry and retrieval of clinical ambulatory data. This screen appears in the patient accounting subsystem. The name of the medical group shown is fictitious. No copyright notice evident.

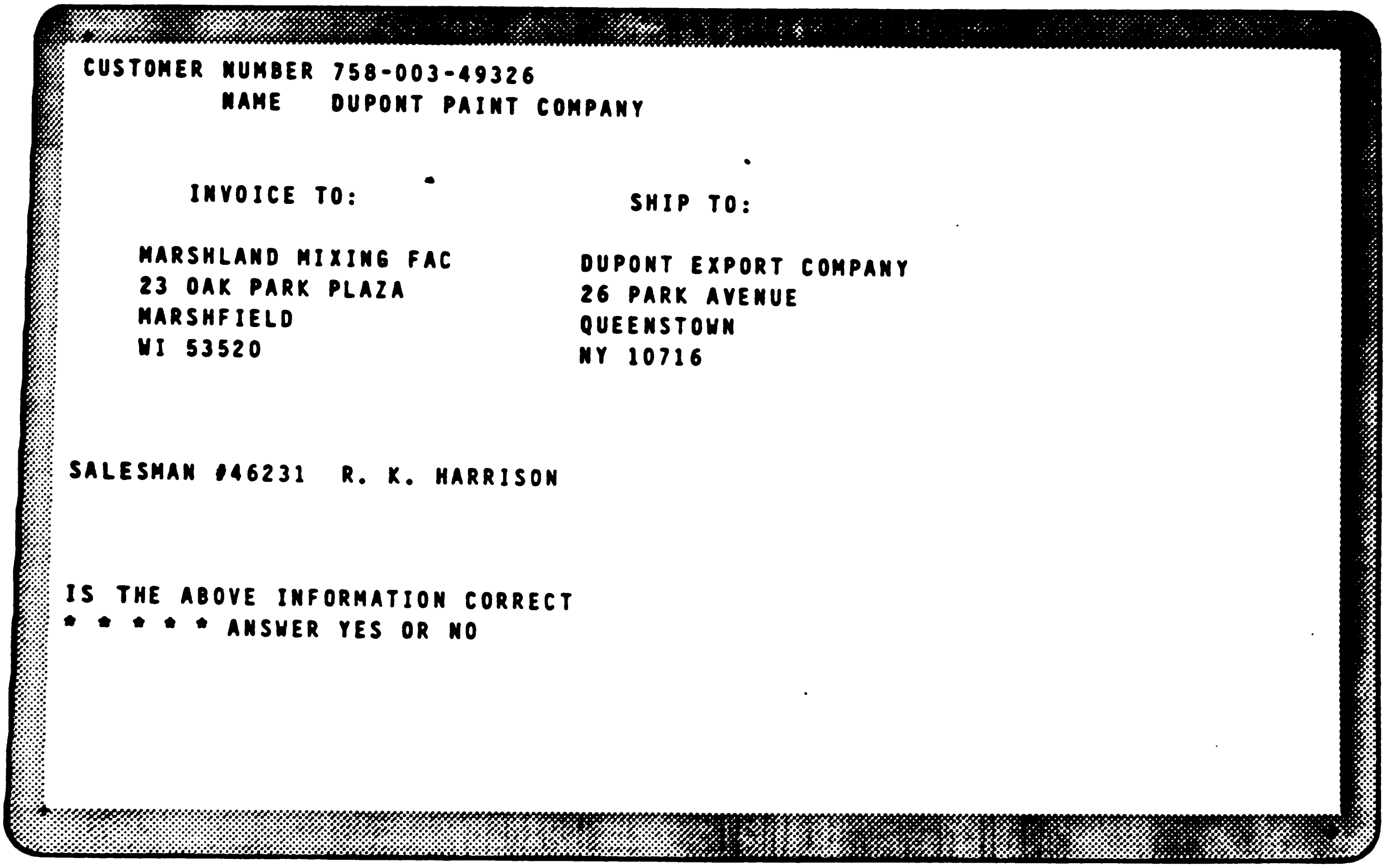
SCREEN NUMBER 9 (CUSTO.SCN)

```
CUSTOMER NUMBER 758-003-49326

NAME  FLANAGAN CHEMICAL COMPANY

INVOICE TO:                 SHIP TO:

HADEN FLATS PLANT           WESTCHESTER PLAINS PLANT

P.O. BOX 783                RTE 1

ENGLEWOOD CLIFFS            YONKERS

NJ 07632                    NY 11216

SALESMAN #53730  B. L. JONES


IS THE ABOVE INFORMATION CORRECT
* * * * * ANSWER YES OR NO
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
15. SHIP TO THIS CITY	"Y"	39	6550 msec.	34.8%
72. CUSTOMER'S NAME	"F"	44	4507 msec.	14.3%

This design was presented by J. Martin as an example of how to "make instructions to the operator stand our and catch his eye immediately." [MART73 p.318, Fig. 17.1]

SCREEN NUMBER 10 (CUST1.SCN)


CUSTOMER NUMBER 758-003-49326
NAME DUPONT PAINT COMPANY

INVOICE TO:

MARSHLAND MIXING FAC
23 OAK PARK PLAZA
MARSHFIELD
WI 53520

SHIP TO:

DUPONT EXPORT COMPANY
26 PARK AVENUE
QUEENSTOWN
NY 10716

SALESMAN #46231 R. K. HARRISON

IS THE ABOVE INFORMATION CORRECT
* * * * * ANSWER YES OR NO

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
16. CUSTOMER'S NAME	"D"	47	5784 msec.	3.9%
73. SHIP TO THIS CITY	"Q"	43	5795 msec.	32.9%

This design is a variant of Screen 9. (See p.A3-9.)

SCREEN NUMBER 11 (DBASE.SCN)

```
RECORD # 20167
NAME       :keiser, stephen p            :
COMPANY    :dean witter reynolds inc     :
ADDR1      :pearlridge          :
ADDR2      :98-211 pali momi st :
CITY       :aiea            :
STATE      :hi:
ZIP        :96701:
TITLE      :account executive            :
W:PHONE    :487-2438        :
H:PHONE    :                    :
COMMENT1   :acct: 147 067 013156                                    :
COMMENT2   :                                                        :
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
17. COMPANY	"D"	48	4047 msec.	7.7%
74. PHONE NUMBER	"4"	45	4826 msec.	0%

This is a screen from dBase II, a database manipulation program which ran on early personal computers. The data was contrived by the author. This basic design continues to appear in later versions of this software including dBase III and dBase III Plus. Copyright, Ashton-Tate Corporation, 1982.

SCREEN NUMBER 12 (DCCABS1.SCN)

```
 HXMRMMR5              GENERAL HOSPITAL ABSTRACT MAINTENANCE
                                          LAST MAINT  1/17/83
MEDRC# 000009003 NAME BANTON, CONSTANCE                          ACCT# 6009003
VISIT# 001       ADMITTED 120981 TIME 1207  DISCHARGED 021782 TIME 0857
ATTEND DR 00002 MISTY, DR. WARREN     ADMIT DR 10111 RYAN,EDWARD
REFER  DR 00067 COVINGTON, JAMES      PRIN SRG 00002 MISTY DR. WARREN
     MOD T/A   DIAG   DESCRIPTION          MOD T/A  DIAG   DESCRIPTION
DIAGN:         250.4  DIABETES WITH RENAL           366.41 CATARACTS
               414.9  CHRO ISCHE HEART DI           278.0  OBESITY
               250.7  DIABETES WITH PERIP           785.4  DIABETIC GANGRENE




     MOD T/A   DIAG   DESCRIPTION          MOD T/A  DIAG   DESCRIPTION
COMP:          785.4  DIABETIC GANGRENE
                                              HOSP COMPLICAT Y  HOSP INFECT Y
          AREA         DAYS    AREA           DAYS    AREA          DAYS
SPEC NURS: 01 ICU      0003
SCHED CLINIC F/UP Y
                    PRESS ENTER TO CONTINUE TO NEXT SCREEN      CMD 4-UPDATE
CMD 6-PREVIOUS  CMD 7-EOJ      CMD 8-RESTART  CMD 9-HELP      CMD 10-EDIT
CMD 13-DSPMSG   CMD 14-SNDMSG  CMD 15-TABLE   CMD 16-DR INQ   CMD 17-DIAG INQ
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
18. ENTER THIS NUMBER TO UPDATE	"4"	45	12846 msec.	25.3%
19. TIME OF DISCHARGE	"0"	48	11273 msec.	7.7%
75. ENTER THIS NUMBER TO RESTART	"8"	39	11664 msec.	32.6%
76. TIME OF ADMISSION	"1"	45	6710 msec.	6.1%

This is a medical records abstract screen which appears in the Dynamic Control hospital information system. This system, whose screens continue to evolve, later became known as Baxter Delta hospital information system. The name of the hospital, the patient and the doctors are fictitious. Copyright, Dynamic Control Corporation, 1983. Used with permission of the authors.

SCREEN NUMBER 13 (DCCLAB1.SCN)

```
RFM00093        MIAMI CHILDREN'S HOSPITAL ORDER STATUS INQUIRY
PATIENT#    ORDER #    PATIENT NAME                          LS ROOM      DR#
 222351      723054    DAWN LOUISE P                         LE  160  B    557
ORDER   DATE     TIME     BY     RESULT   DATE     TIME     BY
        1/30/84 18:58   5723              1/30/84 21:55  2128
 ITEM#   D E S C R I P T I O N....    TECH   SPECIMEN: DATE   TIME
204-3804 BL CHEM PROFILE-8             205     6427J    13084  2108
CHEMISTRY PROFILE 8            (NORMALS)   DRAW FULL MICROTAINER OR 3ML RED TOP
    UREA NITROGEN      9 MG/DL ( 6- 20MG/DL)               PANIC > 35
    SODIUM      NA   144 MEQ/L (135-148MEQ/L)              PANIC <120 OR >160
    POTASSIUM   K    4.9 MEQ/L (3.5-5.9MEQ/L) *            PANIC <2.5 OR >7
    CHLORIDE    CL   103 MEQ/L ( 98 -107 MEQ/L)
    CO2 CONTENT     27.6 MEQ/L (24.0-31.0MEQ/L)            PANIC <10 OR >40
    GLUCOSE          102 MG/DL (76-115 MG/DL)              PANIC <30 OR >300 NEW
    CREATININE       0.6 MG/DL (0.5-1.4 MG/DL)             PANIC >3
    BUN/CREATININE    15
                         DONE BY   205      SECT.CHIEF APP.    210
* UNDER 10 DAYS OLD 3.5-7
 COMMENTS:

                    PRESS ENTER TO CONTINUE TO NEXT SCREEN
CMD  1-F/S INQ   CMD 2-DRUG PROFILE
CMD 6-PREVIOUS   CMD 7-EOJ       CMD 8-RESTART   CMD 9-HELP
CMD 13-DSPMSG    CMD 14-SNDMSG   CMD 15-TABLE    CMD 16-DR INQ   CMD 17-DIAG INQ
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
20. PATIENT'S FIRST NAME	"L"	47	5488 msec.	25.7%
21. POTASSIUM RESULT	"4"	46	7508 msec.	10.3%
77. PATIENT'S LAST NAME	"D"	45	5667 msec.	23.4%
78 SPECIMEN NUMBER	"6"	45	9093 msec.	13.2%

This is a clinical laboratory results reporting screen for serum electrolytes which appears in the Dynamic Control hospital information system. This system, whose screens continue to evolve, later became known as Baxter Delta hospital information system. The name of the patient is fictitious. Copyright, Dynamic Control Corporation, 1983. Used with permission of the authors.

SCREEN NUMBER 14 (DJ1.SCN)

DOW JONES NEWS/RETRIEVAL SERVICE

DAILY QUOTES - HEALTH INFORMATION SYSTEMS, INC.

DATE	BID	ASKED	CLOSE	VOL(100/S)
08/31/83	23 1/4	24		18
09/01/83	23	24		20
09/02/83	23 1/4	24 1/4		309
09/06/83	25 1/4	26 1/4		172
09/07/83	27	27 1/2		55
09/08/83	26 1/2	28		1
09/09/83	26 1/2	27 1/2		9
09/12/83	27 1/2	28 1/2		54
09/13/83	27	28		4
09/14/83	26	27		27
09/15/83	26 3/4	27 1/2		8
09/16/83	26 1/2	27 1/2		27
09/19/83	26 1/2	27 1/2		42
09/20/83	26 1/2	27 1/2		42
09/21/83	26 1/2	27 1/2		1
09/22/83	25 1/2	26		24

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
22. HIGHEST VOLUME	"3"	48	5424 msec.	0%
79. COMPANY	"H"	38	7751 msec.	36.8%

This screen presents daily stock market quotes for consumers who subscribe to this online service. Copyright, Dow Jones News/Retrieval Service, 1983.

SCREEN NUMBER 15 (EUREKA.SCN)

```
                    EUREKA!
       Mendocino Software Company, Inc.
         Ver. 2.11 - Copyright 1984
            Date is -->  4/10/84

        U = Update catalog
        A = Access catalog
        P = Put EUREKA! on new disk
        E = Erase disk from catalog
        D = change Date
        C = select Catalog drive
            ( B = current drive)

        Q = Quit, return to CP/M

        Command ? .
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
23. ENTER THIS LETTER TO CHANGE THE DATE	"D"	48	3945 msec.	2%
24. DATE	"4"	48	3151 msec.	4%
80. ENTER THIS TO QUIT	"Q"	45	4254 msec.	0%
81. VERSION NUMBER	"2"	45	3599 msec.	2.2%

This personal computing software is used to catalog files appearing on a user's disks. It can sort and present the collected information in a variety of forms. Copyright, Mendocino Software Company, Inc., 1984.

SCREEN NUMBER 16   (HNLSFO.SCN)

```
To SAN FRANCISCO,CA                            PST SFO
Fm HONOLULU,OAHU;HAWAII                        HST HNL

         6:50a    2:05p S PA   124 PJYBM 747 B 0
357      7:45a    3:00p S CO     4 PCYBM D10 B 0
                CO 4 EFFECTIVE 15 APR
         9:45a    4:30p S WA   368 FYBQM D10 L 0
        11:10a    5:55p S NW    10 FCYB  D10 L 0
         2:40p    9:30p S UA   186 FYQM  747 L 0
X12      4:30p   11:25p S 6P    18  YK   DC8 S 0
         4:35p   11:06p S AA   160 FYBQM D10 D 0
         4:40p   11:30p S UA   188 FYQM  747 D 0
SPEC    10:00p    5:45a S WA  2370 FYBQM D10 S 0
                      OP 28 APR
        11:00p    5:45a S WA   370 FYBQM D10 S 0
                      EX 28 APR
        11:15p    6:05a S UA   210 FYQM  D10 S 0
        11:25p    6:15a 0 WO    24 YBQK  D10 S 1
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
25. TIME OF FIRST DEPARTURE OF THE DAY	"6"	48	7699 msec.	5.9%
26. NUMBER OF STOPS ON FLIGHT 24	"1"	44	15032 msec.	22.2%
82. DESTINATION CITY	"S"	44	4396 msec.	2.1%
83. TIME OF FIRST DEPARTURE AFTER NOON	"2"	44	9999 msec.	14.0%

This screen provides airline flight schedules between two points (in this example between San Francisco and Honolulu). It is used by travel agents and consumers who can book airline travel via this online service. Copyright, Official Airline Guide, 1984.

SCREEN NUMBER 17 (MEDBI01.SCN)

```
GOLDSTEIN,CHARLES W  100000848  26 M  INP 127 1 W

1221:9003R  COLL: 12/21/77 4:38 PM  LOG: 12/21/77 4:37 PM
   SOURCE: FLUID
   COMMENT: ABDOMINAL PAIN
   ORDERED: MISCELLANEOUS CULTURE

   => GRAM STAIN - 1H - ** FINAL **
           ...RBC DEBRIS WITH RARE POLY.
           ...MANY GRAM NEGATIVE RODS
           ...FEW GRAM POSITIVE COCCI
   => MISCELLANEOUS CULT - 1D 18H - ** FINAL **
           ...MANY ESCHERICHIA COLI
           ...FEW STAPHYLOCOCCUS AUREUS

                    A C C C C E G K M P T T V
                    M A E H L R E A E E E O A
                    P R P L I Y N N T N T B N
                    I B H O N T T A H   R R C
                      E A R D H A       A A O
                      N L O A R

      E COLI        S S S S     S S     S S
      STAPH +           S S S S S S S R S   S
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
27. PATIENT'S LAST NAME	"G"	48	3488 msec.	7.4%
28. NAME OF RESISTANT ANTIBIOTIC	"P"	4	19705 msec.	27.9%
84. SOURCE	"F"	45	2236 msec.	2.2%
85. NAME OF RESISTANT ANTIBIOTIC	"P"	3	18588 msec.	25.0%

This is a clinical laboratory results reporting screen for microbiology. This is a proposed design for a laboratory information system which was never built. Not copyrighted.

SCREEN NUMBER 18 (NASA202.SCN)

PRESENT SITUATION		GMT 1102:15
LAT		LONG
38 17' 42"N		94 52'06"W
WIND	DRIFT	COURSE
292/146	6o L	281
G/S	TAS	TK ERROR
299	348	1o R
AVG WF		XTK ERROR
-100		0.5 L NM
OAT	TEMP D	A/C GROSS WT
-49	7+	408364 LBS

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
29. LATITUDE	"3"	48	3203 msec.	9.3%
30. DRIFT	"6"	41	5528 msec.	16.0%
86. GROSS WEIGHT	"4"	34	7570 msec.	22.4%
87. TEMPERATURE	"7"	45	7368 msec.	14.8%

This screen design was presented to the author for testing and criticism by the NASA-Ames Research Center, Mountain View, California. It is a proposed design to be utilized in one of the space shuttle navigation systems. (Also see Screen 35, p.A3-35.) Not copyrighted.

SCREEN NUMBER 19   (NDSI.SCN)

```
01/20/79     NDSI GROUP SYSTEM              PT BLG    - DISPLAY ACCOUNT
ACCOUNT NO. 346207     RESP. PARTY JOHN SPRADLE
 STREET      2434 TIMMY St.                     BALANCE                 437.00
 CITY        POMONA CA. 96013                   MIN PAYMENT              20.00
 PHONE       (714) 565-2397                     MTD PAYMENT              35.00

INSURANCE    001               MO.  COUNT 04 INTEREST N  INDUSTRIAL N
DUNNING     INVOICE N PAT BILL N COLLECT N  SUSPENSE N PAYMENT PLAN N
PATIENT NAME              MEMB  CHART NUMBER   BIRTHDATE  SEX  R1 R2 DR.#
SPRADLE, DANIELLE          01*   1467-9        11/11/43    F    1  1 001

CORRECT:    Y
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
31. PATIENT'S FIRST NAME	"D"	45	9938 msec.	31.4%
32. ACCOUNT BALANCE	"4"	48	5721 msec.	0%
88. ACCOUNT NUMBER	"3"	45	2191 msec.	0%
89. BIRTH YEAR	"4"	45	8184 msec.	17.5%

This screen design presents accounting information from a medical group management system. The name of the patient is fictitious. Copyright, Northrop Data Systems, Inc., 1979.

SCREEN NUMBER 20 (PUPF1.SCN)

STUDENT SUMMARY GRADE REPORT
OCCIDENTAL UNIVERSITY

NAME Jamieson, Lisa M.
SSN 595-32-1063
AGE 20

SEM	COURSE	SEC	TITLE	PROFESSOR	UNITS	GRADE	POINTS
F82	Psych 101	1	Intro to Psychology	B. Skinner	6	A-	24
F82	Math 160	10	Calculus I	J. Peabody	5	B+	15
F82	Phil 260		Western Thought	F.M. Mizer	4	B-	12
				TOTAL	15		51
				GPA		3.4	
S83	Math 161	9	Calculus II	J. Peabody	5	C-	10
S83	Phys 150	2	Classical Physics	N. Wentworth	6	B	18
S83	ICS 160	1	Intro Comp Science	J.R. Miller	4	A	16
				TOTAL	15		44
				GPA		2.9	

CURRENT GPA-- 3.16

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
33. CURRENT GRADE POINT	"3"	48	4908 msec.	10.9%
34. AGE	"2"	48	2069 msec.	2.0%
90. SOCIAL SECURITY NUMBER	"5"	45	2333 msec.	0%

This screen is from a public-domain student grade reporting system used at a number of universities. The name of the university and the name of the student are fictitious. Not copyrighted.

SCREEN NUMBER 21 (PUPF2.SCN)

```
                         AMHERST UNIVERSITY  STUDENT RECORDS

NAME                      SSN              AGE
Porter, James A.    495-23-1063           19

                                  SEMESTER FALL 1982
COURSE   Psych 101   Math 160       Phil 260                              TOTAL
SEC       1            10
TITLE    Intr Psych  Calculus I     Western Thought
PROF     Skinner B.  Peabody J.     Mizer F.M.
UNITS    6            5             4                                      15
GRADE    A-          B+             B-
POINTS   24          15             12                                     51

                                 SEMESTER SPRING 1983
COURSE   Math 161    Phys 150                                              TOTAL
SEC      9           2
TITLE    Calculus 2  Class Phys
PROF     J. Peabody  N. Wentworth
UNITS    5           6                                                     13
GRADE    C-          A
POINTS   10          24                                                    34
                                                    CURRENT GPA           2.6*
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
35. SOCIAL SECURITY NUMBER	"4"	48	2482 msec.	0%
91. CURRENT GRADE POINT	"2"	45	7233 msec.	2.2%
92. AGE	"1"	45	2522 msec.	2.2%

This screen is from a public-domain student grade reporting system used at a number of universities. The name of the university and the name of the student are fictitious. Not copyrighted.

SCREEN NUMBER 22 (REC1.SCN)

```
                              Welcome
                              to  the

                            RECONSIDER
                    Disease Information System
                          Version  1.1

        (c) Copyright by the Regents of the University of California

Any prompt by the system can be responded to with any of the following:

 <RETURN> - the default response TO CONTINUE <press the RETURN key>
                (action taken depends on the current prompt)

    ?     - HELP (available only at certain prompts)

    q     - back to the PREVIOUS MASTER FRAME

    x     - forward to the "ENTER TERMS" PROMPT
                (if at the "Enter terms" prompt, "b" to END the SESSION)

Enter terms:
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
36. VERSION NUMBER	"1"	48	3700 msec.	2.0%
93. NAME OF SYSTEM	"R"	44	7230 msec.	34.7%

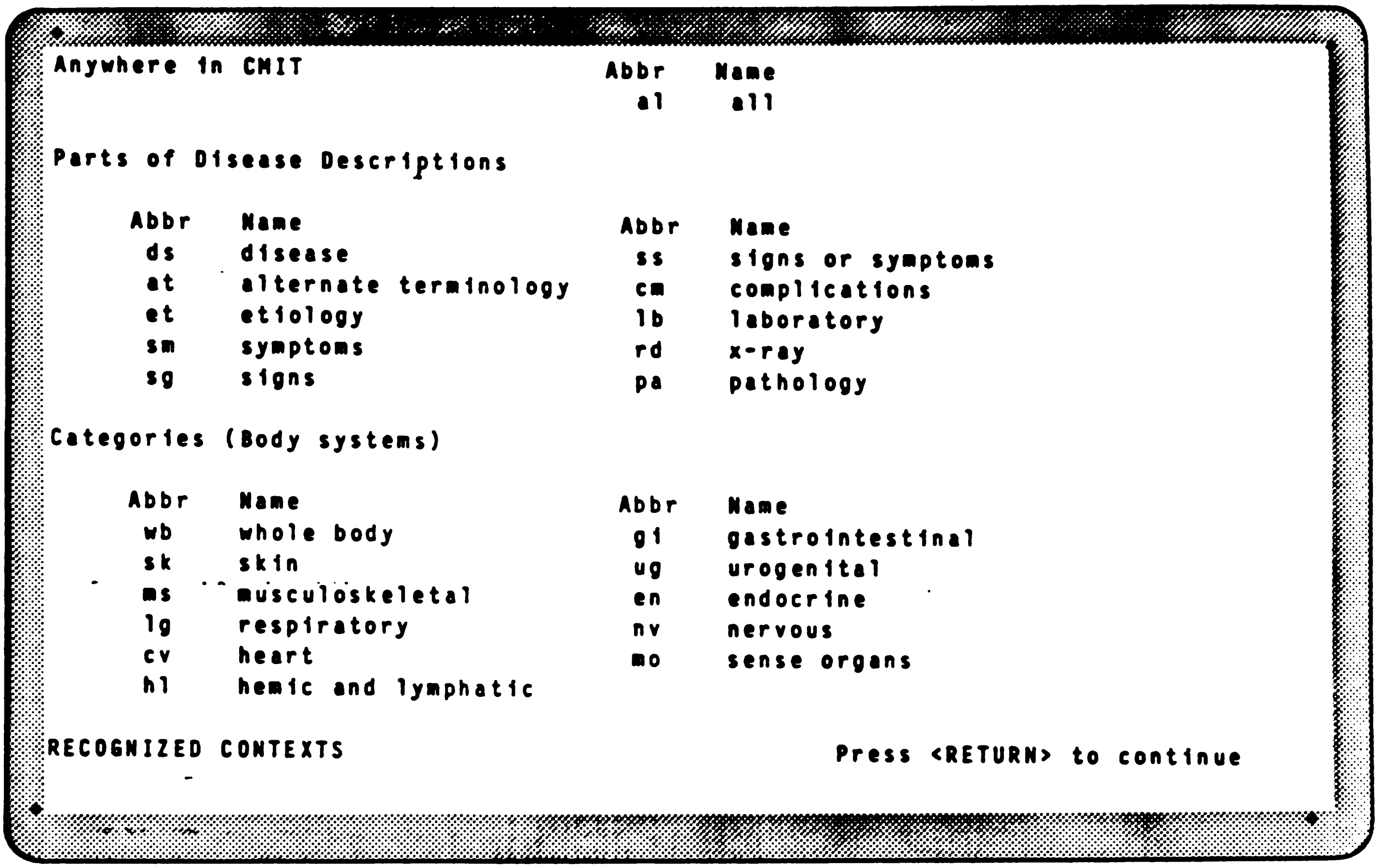
This screen is from an experimental computer-assisted medical diagnosis system called RECONSIDER which was built at the University of California, San Francisco, by researchers in medical computing in the Section on Medical Information Science. Copyright, Regents of the University of California, 1984.

```
Signs or Symptoms: chest pain[83+0] ; fever[519+9].
      8.326 - maximum total score            583 diseases in this list

   1   8.326  pleurodynia, epidemic   00
   2   8.208  rheumatic fever, acute   00
   3   8.019  zinc chloride, toxicity   00
   4   7.323  migraine syndrome   00-09
   5   7.127  diborane, toxicity   00
   6   6.898  amyloidosis of familial mediterranean fever   00
   7   6.432  antidiuretics, action   00
   8   6.431  postcardiotomy syndrome   00
   9   6.426  pneumonia, simple 03
  10   6.008  pleurisy, tuberculous   03
  11   5.898  lung, gangrene 06
  12   4.999  coccidioidomycosis   03-07
  13   4.897  lung, anthrax   03
  14   3.206  lung, sequestration   03
  15   3.112  loeffler syndrome   03
  16   3.000  bronchopneumonia   03
  17   2.998  pleurisy, fibrinous   03
  18   2.442  lung, middle lobe syndrome   03
  19   1.895  lung, alveolar proteinosis   03
More diseases.  Enter 'f' for next screen.
Enter index at left of a disease for more score details. Enter 'q' to quit:
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
37. ENTER THIS TO QUIT	"Q"	48	7975 msec.	10.9%
38. RANKING OF PNEUMONIA	"9"	42	9590 msec.	25.6%
94. ENTER THIS FOR NEXT SCREEN	"F"	45	6332 msec.	16.1%
95. MAXIMUM SCORE	"8"	45	4839 msec.	8.2%

This screen is from an experimental computer-assisted medical diagnosis system called RECONSIDER which was built at the University of California, San Francisco, by researchers in medical computing in the Section on Medical Information Science.

SCREEN NUMBER 24 (REC3.SCN)



Anywhere in CMIT

Abbr	Name
al	all

Parts of Disease Descriptions

Abbr	Name	Abbr	Name
ds	disease	ss	signs or symptoms
at	alternate terminology	cm	complications
et	etiology	lb	laboratory
sm	symptoms	rd	x-ray
sg	signs	pa	pathology

Categories (Body systems)

Abbr	Name	Abbr	Name
wb	whole body	gi	gastrointestinal
sk	skin	ug	urogenital
ms	musculoskeletal	en	endocrine
lg	respiratory	nv	nervous
cv	heart	mo	sense organs
hl	hemic and lymphatic		

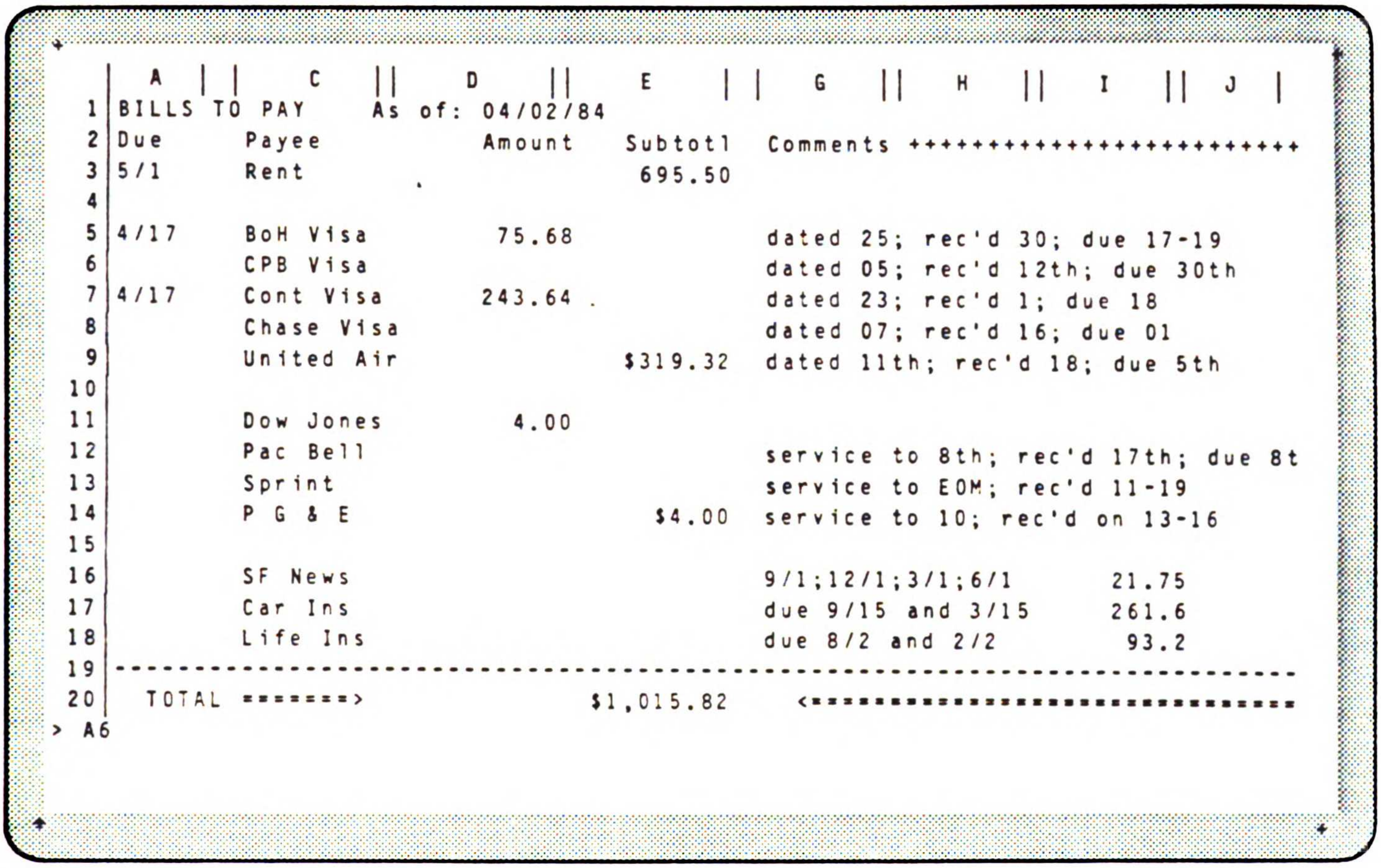
RECOGNIZED CONTEXTS

Press <RETURN> to continue

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
39. ABBREVIATION FOR X-RAY	"R"	48	5154 msec.	2.0%
40. ABBREVIATION FOR THE HEART	"C"	48	5740 msec.	7.4%
96. ABBREVIATION FOR DISEASE	"D"	45	3674 msec.	4.3%
97. ABBREVIATION FOR SENSE ORGAN	"M"	45	10626 msec.	2.2%

This screen is from an experimental computer-assisted medical diagnosis system called RECONSIDER which was built at the University of California, San Francisco, by researchers in medical computing in the Section on Medical Information Science.

SCREEN NUMBER 25 (SC2.SCN)



```
      A ||    C    ||    D    ||    E    ||    G    ||    H    ||    I    ||  J  |
 1 BILLS TO PAY    As of: 04/02/84
 2 Due     Payee         Amount    Subtotl   Comments +++++++++++++++++++++++
 3 5/1     Rent                     695.50
 4
 5 4/17    BoH Visa       75.68               dated 25; rec'd 30; due 17-19
 6         CPB Visa                           dated 05; rec'd 12th; due 30th
 7 4/17    Cont Visa     243.64               dated 23; rec'd 1; due 18
 8         Chase Visa                         dated 07; rec'd 16; due 01
 9         United Air              $319.32    dated 11th; rec'd 18; due 5th
10
11         Dow Jones       4.00
12         Pac Bell                           service to 8th; rec'd 17th; due 8t
13         Sprint                             service to EOM; rec'd 11-19
14         P G & E                   $4.00    service to 10; rec'd on 13-16
15
16         SF News                            9/1;12/1;3/1;6/1        21.75
17         Car Ins                            due 9/15 and 3/15       261.6
18         Life Ins                           due 8/2 and 2/2          93.2
19 ---------------------------------------------------------------------------
20   TOTAL =======>              $1,015.82    <==============================
> A6
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
41. TOTAL	"1" OR "$"	64	3736 msec.	5.9%
98. AMOUNT OF RENT PAYMENT	"6"	29	6784 msec.	6.3%

This screen is typical of the many spreadsheet programs which are available on personal computers. The data was contrived by the author.

SCREEN NUMBER 26 (SMSLAB2.SCN)

```
                    RESULT ENTRY     09/23/1983 04:27PM

PATIENT NO ==>60228           ECKERT, CHARLES   M  32Y
DEPARTMENT ==>LAB
RESULT TYPE==>1
COLL D/T   ==>09/23/83 16:32
ACCESS NO  ==>1
ROUTE TO   ==>LABRST
PH         ==>7.4     <NORMAL: 7.35 - 7.45
COMMENT    ==>
PCO2       ==>35  MM.GH  <NORMAL: 35 - 45
COMMENT    ==>
PO2        ==>80  MM.HG  <NORMAL: 80 - 90
COMMENT    ==>
BICARB     ==>17*      <NORMAL: 22 - 28
COMMENT    ==>
O2 SAT     ==>90*   % <NORMAL: 96 - 97
COMMENT    ==>
SOURCE     ==>ARTERIAL LINE

ENTER?     ==>
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
42. SOURCE	"A"	48	4731 msec.	2.0%
43. PATIENT NUMBER	"6"	48	3010 msec.	4.0%
99. PH VALUE	"7"	45	4011 msec.	2.2%
100. PATIENT'S LAST NAME	"E"	45	3275 msec.	2.2%

This is a clinical laboratory results reporting screen for blood gases which appears in the SMS laboratory information system. The name of the patient is fictitious.

SCREEN NUMBER 27 (SPEADM1.SCN)

```
FORMAT: INQPT1                                   PRINTED: 04/16/83 15:55:16
INQPT1
==============================================================================
                        P a t i e n t   I n f o r m a t i o n
==============================================================================
Number:    40002407                       Medical Record Number:  815 3609
Name:      Amao, Remedios                 Birthdate: 06/30/1920  Age: 63
Other:                                    Radiology Number:       428791-8
Address:   4589 Lexington #4              District:
City:      Los Angeles                    State: CA        Zip: 90024
Phone:     664-0597                       Sex: F           Marital Status: M
Soc Sec:   553-17-3672                    Religion: RC     Racial Origin: F

==============================================================================
               P a t i e n t   E m p l o y e r   I n f o r m a t i o n
==============================================================================
Code:      PRI                            Occupation: clerk
Name:      Medeiros Insurance Company     Length of Employment: 27 Y
Address:   2227 Sunset Blvd               Phone: 898-8790
City/St:   Hollywood CA 90021             Clock #:

                                TAB When Done: _

Patient Name: Amao, Remedios                        No: 40002407  Room: 216B
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
44. PATIENT'S LAST NAME	"A"	48	5180 msec.	9.3%
101. PATIENT'S FIRST NAME	"R"	45	3961 msec.	2.2%

This is the patient registration from from a medical office software system design, created by an undergraduate student of Computer Science at the University of Hawaii. The name of the patient is fictitious. Not copyrighted.

SCREEN NUMBER 28 (STDNOT1.SCN)

```
                         *CLINIC HEALTH REPORT*

BARLETTA,TONY  #666884444                     PROBLEM:  HEADACHE
MALE AGE: 58 DOB: JAN 26,  36                 VISIT: 3
  AUG 30, 77
   WT: 201   TEMP: 98.8    BP: 140/60

SUBJECTIVE
   PAT CONTINUES TO HAVE PERIODIC SPELLS

OBJECTIVE
   MONITOR

PLAN
TESTS
   COMPLETE BLOOD COUNT
      HEMATOCRIT (42-50 ): 45
      WHITE BLOOD COUNT (4500-11000 MM3): 12000*
      RED BLOOD COUNT (4.6-6.2 MILLION/MM3): 5
   POTASSIUM (3.5-5.0 MEQL): 6*
   SODIUM: 123

MEDICATION
   ACETOPHENAZINE: 2 TABS FOR 3 DAYS
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
46. WEIGHT	"2"	48	5316 msec.	7.7%
47. PATIENT'S MEDICAL PROBLEM	"H"	48	6140 msec.	9.1%
103. AGE	"5"	43	3542 msec.	9.4%
104. MEDICATION	"A"	44	5652 msec.	2.2%

This is a screen from COSTAR, a pioneering effort in automating the entry and retrieval of clinical ambulatory data, organized in a problem-oriented manner. Later medical computing projects involving POMR data have borrowed heavily from this design. It was designed at Mass. General Hospital and at MIT in the late 1960's. No copyright notice evident.

SCREEN NUMBER 29 (STEWART1.SCN)

```
PART NUMBER FILE   SUB-FILE MISC BKTS

SUPPLIER J.BLOGGS & SON, ROTHERHAM

PART 926431X  DESCRIPTION L11 BRONZE STUD BRACKET

SUB-ACCOUNT 92 BUDGET GROUP 2413

QUANTITY UNIT DOZENS DEPRECIATION PERIOD 15 ACTION

DATE OF ADDITION 12/1/75  ADDED BY F.BRIGGS DES 9

DATE LAST AMENDED 5/14/75  AMENDED BY PROC 11 R.SMITH

GROUP B CLASS R STATUS NOT YET ALLOCATED

DATE OF DELETION

COMPONENTS NONE

SUB ASSEMBLIES. NONE
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
48. PART NUMBER	"9"	48	7074 msec.	17.2%
49. STATUS	"N"	39	13643 msec.	22.7%
105. SUPPLIER	"J"	45	2941 msec.	0%

This screen design is presented as a "Bad Format" by T.F.M. Stewart. [STEW76A, p.162] Stewart also suggests a "Better Format", see Screen 30 (p.A3-30).

SCREEN NUMBER 30 (STEWART2.SCN)

```
PART NUMBER FILE:

PART:       74261812              LH BRONZE STUD BRACKET

GROUP:      J                     BUDGET GROUP:          3612

CLASS:      Z                     SUB-ACCOUNT:           45

UNITS:      DOZENS                DEPRECIATION PERIOD:   81

ACTION      NONE                  STATUS:       NOT YET ALLOCATED

ADDITION DATE:                    3 DEC 76      F.BRIGGS DES 9

LAST AMENDED                      21 JUL 75     R.SMITH PROC 11

DELETION DATE:                    NONE

MAIN SUPPLIER:                    L.R. RICHARDSON, AMSTERDAM
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
50. SUPPLIER	"L"	48	6754 msec.	2.0%
106. STATUS	"N"	45	5502 msec.	6.3%
107. PART NUMBER	"7"	45	3752 msec.	0%

This screen design is presented as a "Better Format" by T.F.M. Stewart. He also presents a "Bad Format", see Screen 29 (p.A3-29). He suggests that "grouping of many similar items...allows them to be searched and identified more accurately and more quickly." [STEW76A, p.162]

SCREEN NUMBER 31 (STOR1.SCN)

```
STEWART, MARY SOVONIA          0647573-6    CLINIC:RDC   DOCTOR: WHITINGOKEEFE
================================================================================

 PROBLEMS/MANIFESTATIONS      STATUS     INFO2      DATE      UNITS     ONSET
----------------------------- --------   --------   --------  -------   --------
 1.1 POLYMYALGIA RHEUMATIC*   +/-        ACTIVE     02-03-83            1978-
11.    WEAKNESS (UPPER EXT)   0/0                   02-03-83  0-4 UE/L  1977
19.    FATIGUE                1                     02-03-83  0-3 SCAL   8-01-79
21.    ARTHRALGIA             0                     02-03-83  0-3 SCAL   9-18-80
36.    MYALGIA                1                     02-03-83  0-3
 7.  AODM                     POOR                  02-03-83  CONTROL    5-27-80
12.  CARDIOMYOPATHY                                                      6-26-80
13.    PREMATURE ATRIAL ARRY  7                     10-09-80  #/MINUTE   6-26-80
20.    PEDAL EDEMA            2+                    02-03-83  0-3 R/L   -
23.    ORTHOPNEA               ?                    01-13-83  0-3       -
28.    LBBB
30.    RALES                  1/0                   02-03-83  0-3 L/R
41.  PAIN, ABDOMINAL          3                     02-03-83  0-3        7-02-81
27.    ANTRITIS                ?ACTIVE              02-03-83  0-3       1-81
42.    BILE GASTRITIS/ESOPH    ?ACTIVE              02-03-83  0-3
45.  PAST MEDICAL HX
 3.    S/P SUP THROMBOPHLEBI  2                     02-03-83  LEG PAIN  APRIL 80

...CONT:
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
51. PATIENT'S FIRST NAME	"M"	48	3249 msec.	4.0%
52. ONSET OF FATIGUE	"8"	44	8820 msec.	27.0%
108. PATIENT'S LAST NAME	"S"	45	3469 msec.	2.2%
109. STATUS OF PAIN	"3"	45	11163 msec.	14.3%

This screen is from a ambulatory care clinical information system called STOR which was built at the UCSF hospitals. The patient name is fictitious. Copyright, Regents of the University of California, 1984.

SCREEN NUMBER 32 (STOR3.SCN)

692202-3	LOTT,DOROTHY	08/07/1922	60	F
726754-1	LUTHI,DEBORAH MAE	03/05/1948	35	F
045682-9	LATO,ELVIRA VITTORIA	03/17/1960	23	F
665817-2	LEDDY,ELIZABETH	11/25/1931	51	F
014018-0	LLOYD,EUGENIA	03/01/1930	53	F
380706-5	LLOYD,EILEEN ISABELLE	08/01/1933	49	F
596394-0	LOTT,ELLA WEASE	07/03/1927	55	F
594925-4	LUHT,EILEEN	08/13/1915	67	F
799338-2	LADIA,FELECISIMA YABOT	08/12/1916	66	F
213606-6	LLOYD,FERMER	12/12/1910	72	F
628806-2	LLOYD,FRANCES ELLSWORTH	02/24/1910	73	F
853664-3	LLOYD,FRANCEEN	01/03/1949	34	F
783472-1	LADD,GRACE BEULAH	06/21/1912	70	F
512186-8	LEDDY,GENEVIEVE V	12/21/1903	79	F
618304-2	LLOYD,GRACE V	08/20/1898	84	F
803531-8	LEETE,GLADYS	11/10/1933	50	F
350935-4	LLOYD,GISELA RITA	07/04/1934	49	F
429025-4	LLOYD,HAZEL	04/22/1907	76	F
798330-1	LLOYD,GLORIA DEAN	01/28/1945	38	F
878846-4	LLOYD,GAIL LYNN	12/07/1951	31	F
709939-4	LOYD,GWENDOLYN ANN	04/09/1948	35	F
697963-7	LEDAY,HAZEL	04/14/1916	67	F
574910-1	LEITE-AH YO,HARVELEE	07/03/1953	29	F

QUESTION ASKED: (unsorted example)	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
53. AGE OF GRACE LLOYD	"8"	48	9733 msec.	15.5%
54. PATIENT NUMBER OF HAZEL LLOYD	"4"	48	8806 msec.	7.7%

This screen is from a ambulatory care clinical information system called STOR which was built at the UCSF hospitals. In this example, the patient names are "partially sorted" or "bucket sorted". (Also see Screen 33, p.A3-33.) Copyright, Regents of the University of California, 1984.

SCREEN NUMBER 33 (STOR3A.SCN)

799338-2	LADIA,FELECISIMA YABOT	08/12/1916	66	F
783472-1	LADD,GRACE BEULAH	06/21/1912	70	F
045682-9	LATO,ELVIRA VITTORIA	03/17/1960	23	F
697963-7	LEDAY,HAZEL	04/14/1916	67	F
665817-2	LEDDY,ELIZABETH	11/25/1931	51	F
512186-8	LEDDY,GENEVIEVE V	12/21/1887	95	F
803531-8	LEETE,GLADYS	11/10/1904	79	F
574910-1	LEITE-AH YO,HARVELEE	07/03/1953	29	F
380706-5	LLOYD,EILEEN ISABELLE	08/01/1933	49	F
014018-0	LLOYD,EUGENIA	03/01/1930	53	F
213606-6	LLOYD,FERMER	12/12/1910	72	F
853664-3	LLOYD,FRANCEEN	01/03/1949	34	F
628806-2	LLOYD,FRANCES ELLSWORTH	02/24/1912	71	F
350935-4	LLOYD,GISELA RITA	07/04/1933	49	F
618304-2	LLOYD,GRACE V	08/20/1898	84	F
798330-1	LLOYD,GLORIA DEAN	01/28/1945	38	F
878846-4	LLOYD,GAIL LYNN	12/07/1951	31	F
429025-4	LLOYD,HAZEL	04/22/1907	76	F
692202-3	LOTT,DOROTHY	08/07/1922	60	F
596394-0	LOTT,ELLA WEASE	07/03/1927	55	F
709939-4	LOYD,GWENDOLYN ANN	04/09/1948	35	F
594925-4	LUHT,EILEEN	08/13/1915	67	F
726754-1	LUTHI,DEBORAH MAE	03/05/1948	35	F

QUESTION ASKED: (sorted example)	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
110. AGE OF GRACE LLOYD	"8"	45	6803 msec.	10.0%
111. PATIENT NUMBER OF HAZEL LLOYD	"4"	45	6577 msec.	13.2%

This screen is from a ambulatory care clinical information system called STOR which was built at the UCSF hospitals. It has been modified by sorting the names on the screen. The astute reader will notice that the names are not completely alphabetically sorted. (Also see Screen 32, p.A3-32. Copyright, Regents of the University of California, 1984.)

SCREEN NUMBER 34   (WBHLAB1.SCN)

```
     Desert Community Hospital, Clinical Pathology, Sun City, AZ  80365
Report Time: 04/08/83 1545    VDP TT1967           Route To: FOXLEE,RICHARD MD
---------------------------------------------------------------------------------
   Spec. Type: BLOOD
Test Name                Result Norm Range      Test Name          Result Norm Range

Na  (mEq/l):               141   136-145        Trig  (mg/dl):        155 * 10-150
K  (mEq/l):                4.0   3.5-5.0        Ca  (mg/dl):          9.2   8.5-10.5
Cl  (mEq/l):               106   96-106         Phos  (mg/dl):        3.8   2.5-4.5
CO2  (mEq/l):               27   24-30          Alk Phos  (U/l):      133 * 30-115
BUN  (mEq/l):               13   6-26           SGOT  (U/l):           28   0-41
Creat  (mg/dl):            0.8   0.70-1.70      LDH  (U/l):           145   60-200
Tot Prot  (g/dl):          7.3   6.0-8.5        CPK  (U/l):            63   0-225
Album  (g/dl):             4.4   3.0-5.5        (Na+K)-(Cl+CO2):     12.0
T. Bili  (mg/dl):          0.5   0.2-1.2        A/G:                  1.5
Dir Bili  (mg/dl):         0.1   0.0-0.4
Gluc  (mg/dl):              92   70-115
Uric Acid  (mg/dl):        2.7   2.2-2.7
Chol  (mg/dl):             191   140-270


---------------------------------------------------------------------------------
Log-in Time: 04/08/83 1428    Fri Apr 08,1983              PARTON, BETTY J
                         SMAC                              1327550 O/P-CLINIC(PHYS)
```

QUESTION ASKED:	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
55. PATIENT'S LAST NAME	"P"	48	8880 msec.	21.5%
112. DOCTOR'S LAST NAME	"F"	45	11199 msec.	30.4%

This is a clinical laboratory results reporting screen for serum electrolytes from a laboratory information system in use at William Beaumont Hospital, Detroit, Michigan. The patient name is fictitious. No copyright notice. Used with the permission of the author.

SCREEN NUMBER 35 (NASA202A.SCN)

```
--PRESENT SITUATION--      GMT  8:24:15

LAT                        LONG

 61 07'31"N                 26 18'33"E

WIND          DRIFT        COURSE

 187/116       3o R         021

G/S           TAS          TK  ERROR

 487           530          4o  L

AVG WF                     XTK ERROR

 -241                       0.5 L NM

OAT           TEMP D       A/C GROSS WT

 -79            16+         717262 LBS
```

QUESTION ASKED: (NASA example)	CORRECT RESPONSE	n	RESPONSE TIME	ERROR RATE
56. GROSS WEIGHT	"7"	38	8189 msec.	21.3%
57. TEMPERATURE	"1"	45	6648 msec.	8.0%
113. LATITUDE	"6"	43	2820 msec.	0%
114. DRIFT	"3"	39	4791 msec.	11.1%

This screen is a variant of Screen 18 (p.A3-18). In this variant the field alignment cues have been modified slightly. Not copyrighted.

APPENDIX 4:

EXPERIMENTAL MATERIALS
Sample Excerpt from Experiment Log

The following is a printout of the log produced during one subject's session. For a complete description of the columns, please refer to Chapter 2, section 2.3.4. The dependent variable in this experiment, Response Time (in msec.), is highlighted.

type log502.ex4

502	1	4	9	5	36	0	0	72	72	7635		A:CIS2.SCN: enter this to explain access
502	2	4	21	13	74	0	0	54	54	10961		A:DCCLAB1.SC: specimen number
502	3	4	47	28	90	0	0	65	65	6207		A:STDNOT1.SC: medication
502	4	4	20	13	11	0	0	68	76	6811	W	A:DCCLAB1.SC: patientz last name /D/ /L/
502	5	4	4	2	16	0	0	50	50	4562		A:BURPRE1.SC: age
502	6	4	24	15	87	0	0	50	50	3143		A:EUREKA.SCN: version number
502	7	4	22	14	60	0	0	72	68	9218	W	A:DJ1.SCN: company /H/ /D/
502	8	4	33	20	1	0	0	53	53	2802		A:PUPF1.SCN: social security number
502	9	4	18	12	38	0	0	56	56	13288		A:DCCABS1.SC: enter this number to restart
502	10	4	52	31	72	0	0	51	51	8078		A:STOR1.SCN: status of pain
502	11	4	5	2	19	0	0	82	0	-1	T	A:BURPRE1.SC: husbandz first name
502	12	4	44	27	12	0	0	82	82	3869		A:SPEADM1.SC: patientz first name
502	13	4	11	6	48	0	0	65	81	20880	W	A:CIS3.SCN: airline offering lowest round trip
502	14	4	45	27	94	1	0	67	67	8693		A:SPEADM1.SC: patientz occupation
502	15	4	25	16	42	0	0	83	83	4552		A:HNLSFO.SCN: desS tinNation city
502	16	4	54	33	92	1	0	52	52	9644		A:STOR3A.SCN: patient number of Haizel Llovd
502	17	4	42	26	77	0	0	55	55	7833		A:SMSLAB2.SC: p h value
502	18	4	11	6	48	0	1	65	65	25653		A:CIS3.SCN: airline offering lowest round trip
502	19	4	22	14	60	0	1	72	68	3945	W	A:DJ1.SCN: company /H/ /D/
502	20	4	5	2	19	0	1	82	82	27526		A:BURPRE1.SC: husbandz first name
502	21	4	22	14	60	0	2	72	72	10643		A:DJ1.SCN: company
502	22	4	37	23	96	0	0	70	70	6372		A:REC2A.SCN: enter this for next screen
502	23	4	15	9	59	0	0	70	70	4830		A:CUST0.SCN: customerz name
502	24	4	56	35	83	0	0	54	54	3691		A:NASA202A.S: latitude
502	25	4	6	3	14	0	0	52	52	21966		A:BURSUR1.SC: patientz identifier
502	26	4	19	12	95	0	0	49	49	13727		A:DCCABS1.SC: time of admission
502	27	4	8	4	34	0	0	66	66	5971		A:CIS1.SCN: enter this for an I B M computer
502	28	4	26	16	46	0	0	50	50	18687		A:HNLSFO.SCN: time of first departure after noc
502	29	4	17	11	64	0	0	52	52	7804		A:DBASE.SCN: phone number
502	30	4	55	34	6	0	0	70	80	18334	W	A:WBHLAB1.SC: doctErz last name /F/ /P/
502	31	4	39	24	27	0	0	68	68	2898		A:REC3.SCN: abbreviation for dizease
502	32	4	31	19	50	0	0	51	51	1971		A:NDSI.SCN: account number
502	33	4	53	33	91	0	0	56	56	6661		A:STOR3A.SCN: age of Brace Lloyd
502	34	4	51	31	11	0	0	83	83	4189		A:STOR1.SCN: patientz last name
502	35	4	2	1	31	0	0	53	53	4190		A:AID2.SCN: enter this to create a new table
502	36	4	48	29	68	0	0	74	74	7163		A:STEWART1.S: supplYer
502	37	4	13	7	54	0	0	52	52	10638		A:COSTAR2.SC: amount of payment
502	38	4	30	18	82	0	0	55	55	8446		A:NASA202.SC: temperature
502	39	4	28	17	78	0	0	80	0	-1	T	A:MEDBIO1.SC: name of resistent anteeby ottik
502	40	4	23	15	40	0	0	81	81	5338		A:EUREKA.SCN: enter this to quit
502	41	4	1	1	88	0	0	83	83	5672		A:AID2.SCN: file name
502	42	4	7	3	24	0	0	65	65	9493		A:BURSUR1.SC: blood type
502	43	4	14	8	56	0	0	49	51	10803	W	A:COSTAR3.SC: cost of brief examination /1/ /
502	44	4	20	13	11	0	1	68	68	7353		A:DCCLAB1.SC: patientz last name
502	45	4	40	24	29	0	0	77	77	11048		A:REC3.SCN: abbreviation for sense orggen
502	46	4	55	34	6	0	1	70	80	19343	W	A:WBHLAB1.SC: doctErz last name /F/ /P/
502	47	4	32	19	21	0	0	52	52	10909		A:NDSI.SCN: birth year
502	48	4	49	30	97	0	0	78	78	4113		A:STEWART2.S: stat us
502	49	4	35	21	16	0	0	49	49	2906		A:PUPF2.SCN: age
502	50	4	3	2	11	0	0	66	66	8685		A:BURPRE1.SC: patientz last name
502	51	4	10	6	43	0	0	52	56	6924	W	A:CIS3.SCN: lowest one way air fare /4/ /8/
502	52	4	55	34	6	0	2	70	70	20505		A:WBHLAB1.SC: doctErz last name
502	53	4	27	17	75	0	0	70	70	3147		A:MEDBIO1.SC: source
502	54	4	41	25	52	0	0	49	49	6189		A:SC2.SCN: total
502	55	4	12	7	6	0	0	87	87	3167		A:COSTAR2.SC: doctErz last name
502	56	4	29	18	17	0	0	52	50	7017	W	A:NASA202.SC: wait /4/ /2/
502	57	4	43	26	11	0	0	69	69	4274		A:SMSLAB2.SC: patientz last name
502	58	4	38	23	53	0	0	56	56	5566		A:REC2A.SCN: max imum score
502	59	4	28	17	78	0	1	80	69	28563	W	A:MEDBIO1.SC: name of resistent anteeby otti
502	60	4	29	18	17	0	1	52	50	16403	W	A:NASA202.SC: wait /4/ /2/
502	61	4	10	6	43	0	1	52	52	9641		A:CIS3.SCN: lowest one way air fare
502	62	4	50	30	66	0	0	55	55	4121		A:STEWART2.S: part number
502	63	4	34	21	4	0	0	50	50	10973		A:PUPF2.SCN: current grade point average
502	64	4	57	35	89	0	0	51	51	4699		A:NASA202A.S: drift
502	65	4	28	17	78	0	2	80	0	-1	T	A:MEDBIO1.SC: name of resistent anteeby otti
502	66	4	16	10	62	0	0	81	81	10791		A:CUST1.SCN: ship to this city
502	67	4	28	17	78	0	3	80	69	21286	W	A:MEDBIO1.SC: name of resistent anteeby ottik
502	68	4	14	8	56	0	1	49	51	20697	W	A:COSTAR3.SC: cost of brief examination /1 /
502	69	4	46	28	16	0	0	53	53	4414		A:STDNOT1.SC: age
502	70	4	14	8	56	0	2	49	53	23247	W	A:COSTAR3.SC: cost of brief examination /1/ /
502	71	4	29	18	17	0	2	52	50	17062	W	A:NASA202.SC: wait /4/ /2/
502	72	4	36	22	86	0	0	82	82	9681		A:REC1.SCN: name of system