DOCUMENT RESUME

ED 179 198 IR 007 859

AUTHOR	Curran, Thomas E.; Mecherikoff, Michael
TITLE	Toward More Comprehensible Technical Manual Graphics. Final Report, November 1977 through September 1978.
INSTITUTION	Navy Personnel Research and Development Center, San Diego, Calif.
SPONS AGENCY	Naval Ship Research and Development Center, Washington, D.C.
REPORT NO	NPRDC-TR-79-28
PUB DATE	Jul 79
NOTE	110p.; Appendices A, B and D removed prior to filming
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Educational Research; *Graphic Arts; Instructional Materials; *Manuals; Media Research; Military Training; *Production Techniques; *Technical Illustration; Technical Writing; *Written Language

ABSTRACT

Several alternative methods of presenting written material within a graphic were evaluated to provide empirical data on how technical writers and artists might improve the comprehensibility of graphics. The number, location, and sequence of "callouts"--the pictorial part references using arrows--were systematically varied in a series of drawings and tested on samples of Navy trainees. The major finding indicated that arranging callouts sequentially provides for good comprehension, even when the number of callouts is large. It is recommended that clarification of the graphic comprehension issue be pursued through empirical studies of users' information-search behavior and the stimulus variations that influence its effectiveness. (Author/CMV)

NPRDC TR 79-28

July 1979

TOWARD MORE COMPREHENSIBLE TECHNICAL MANUAL GRAPHICS

Thomas E. Curran

Michael Mecherikoff
EG&G Washington Analytical
Services Center, Inc.
Bethesda, Maryland 20084

Reviewed by
Robert E. Blanchard

Approved by
James J. Regan
Technical Director

Navy Personnel Research and Development Center
San Diego, California 92152

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NPRDC TR 79-	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TOWARD MORE COMPREHENSIBLE TECHNICAL MANUAL GRAPHICS		5. TYPE OF REPORT & PERIOD COVERED Final Nov 1977 - Sep 1978 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Thomas E. Curran Michael Mecherikoff EG&G Washington Analytical Services Center, Inc.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Navy Personnel Research and Development Center, San Diego, California 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZF55522003 62757N
11. CONTROLLING OFFICE NAME AND ADDRESS Navy Technical Information Presentation Program D. W. Taylor Naval Ship Research and Development Center, Bethesda, MD 20084		12. REPORT DATE July 1979 13. NUMBER OF PAGES 127
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Graphics	Usability
Illustrations	Maintenance
Technical	Readability
Comprehensibility	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Although technical manuals often consist primarily of graphic material, there is a virtual absence of empirical data on how technical writers and artists might improve the comprehensibility of graphics. This study, sponsored by the Navy Technical Information Presentation Program, evaluated several alternate methods of presenting written material within a graphic. The number, location and sequence of "callups" were systematically varied in a series of drawings and tried out experimentally on samples of Navy

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) trainees. The major finding was that arranging callouts sequentially provides for good comprehension, even when the number of callouts is large.

FOREWORD

This research and development was performed in support of the Navy Technical Information Presentation Program (NTIPP) under the auspices of the Naval Ship Research and Development Center, Bethesda, Maryland. NTIPP's goal is to develop a system of procedures and equipments designed to improve the utility, preparation, revision, storage, distribution, and management of technical information for the mid-1980s. This Center was tasked with investigating a problem fundamental to this goal--assessment of comprehensibility and usability of graphic materials in technical information.

This report, the first in a series, covers the first phase of this work. It details the findings of a study dealing with the location and identification of information on technical drawings, outlines initial guidelines pertinent to graphic comprehensibility, and provides an approach for further exploration of these critical issues.

DONALD F. PARKER
Commanding Officer

SUMMARY

Problem

Current graphic practices for technical manuals, as set forth in military specifications, standards, handbooks, and other publications, are rarely based on objective evidence that they improve use and comprehension. Methods based on valid data are not currently available either for establishing requirements for procuring technical manuals or for objectively measuring a particular illustration's effectiveness in supporting the job performance of technical personnel.

Objective

The overall purpose of this research and development was to begin the development of empirically based guidelines and objective measurement techniques to increase the use of technical illustrations. Toward this end, four specific objectives were established:

1. To identify a limited set of features that could be hypothesized as facilitating or inhibiting the use of illustrations.

2. To construct technical illustrations displaying variations of these features.

3. To measure the performance of Navy technicians extracting selected information from these illustrations.

4. To evaluate the potential of the present methodology for future research.

Approach

The features selected for study were the number, sequence, and physical arrangement of callouts or index numbers used by technicians in locating or identifying parts on illustrations. Starting with two illustrations from existing technical manuals--a cross-sectional view and an exploded view--these features were varied in a large number of combinations. The experimental tasks of locating and identifying target information, given selected entry information, were designed to simulate on-the-job tasks as realistically as possible and still be amenable to precise measurement in terms of the time required to complete the task. Subjects were 243 Navy enlisted men in three separate ratings who were familiar to some extent with the use of technical illustrations.

Findings

1. For the task of finding a part on an illustration when given a callout number:

a. When numbers were in sequence, there was little difference in search time as the number of callouts increased from 10 to 62.

b. When numbers were in random order, search time increased by a factor of three or four as the number of callouts increased from 10 to 62.

c. Including both the nomenclature and the number in the callout did not interfere with the search for a number.

2. For the task of finding a part on an illustration when given the nomenclature of that part (with the nomenclature either in the callout itself or in an accompanying table):

a. For 10 callouts, scanning nomenclature callouts was more efficient than using a table.

b. When the number of callouts was larger (27 or greater), searching a table, even when not alphabetical, was superior to scanning nomenclature callouts on the drawing itself.

c. As the number of callouts increased from 10 to 62, median search time increased by a factor of about six.

d. When callouts contained both numbers and nomenclature, the numbers tended to interfere with finding a part name.

3. For the task of giving the nomenclature of a marked part (using either nomenclature in the callout itself or in an accompanying table):

a. There was a small increase in search time from 10 to 27 callouts when a table was used, and no increase beyond that.

b. Where nomenclature was in the callouts, increasing the number of callouts yielded no difference in response time.

c. For 10 callouts, using a table or having numbers in the callout itself were equally efficient; for larger numbers of callouts, there was an advantage to having nomenclature in the callouts even when the number of callouts was large and the drawing appeared cluttered.

4. Findings with regard to the physical appearance of callouts (e.g., the circling of a number versus not circling it) were inconsistent but appeared weak in comparison with the effects of sheer number of callouts and the sequence versus random variable.

5. The general methodology employed was found to be flexible and relatively efficient and allowed for variations depending on the particular type of task in which the technician might be engaged.

Conclusions and Recommendations

1. For part location by callout number, always arrange the callouts in numerical order.

2. For part location by nomenclature, use nomenclature callouts if the number of callouts is 10 or less; otherwise, use number callouts in sequence keyed to an alphabetical table.

3. For part identification (finding the nomenclature when the location is known), use nomenclature callouts even when the number of callouts is large and the drawing looks cluttered. There are no data on the upper limit.

4. If the numbers are in sequence, then devices to enhance discrimination and visual scanning, such as circling and aligning the callout numbers, are probably unnecessary.

5. Zones are not useful for locating parts when a callout number must also be used for verification.

6. Since the guidelines differ with the type of information-search task, each drawing must be designed for the specific task it is intended to support.

7. Although it appears promising to isolate the information-search behaviors of technical manual users and to vary the drawing features that influence search speed and accuracy, care must be taken in future studies to randomize, counterbalance, or measure the effect of target location in the stimulus materials.

8. Clarification of the graphic comprehension issue should be pursued through empirical studies of users' information-search behavior and the stimulus variations that influence its effectiveness.

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INTRODUCTION

Problem

Since illustrations may easily make up 50 percent or more of a technical manual, the effectiveness of graphics in communicating technical information is critical. Requirements for current graphic practices, as set forth in military specifications, standards, handbooks, and other publications, are rarely based on objective evidence that they improve technical manual use and comprehension. Requirements in different documents sometimes contradict each other. At present, there are no methods based on valid data either for establishing requirements for procuring technical manuals or for objectively measuring a particular illustration's effectiveness in supporting the job performance of technical personnel.

Objective

The overall objective of this research was to begin development of empirically based guidelines and objective measurement techniques to increase the use of illustrations in technical manuals.

The specific objectives of this study were:

1. To identify a limited set of features that can be hypothesized as either facilitating or inhibiting the use of illustrations.

2. To construct technical illustrations displaying variations of these features.

3. To measure the performance of Navy technicians in extracting selected information from the illustrations.

By systematically varying a small number of well-defined features and objectively measuring the effect on specific tasks simulating actual use, the following goals can be achieved:

1. A quantitative index of effectiveness, such as time-to-locate-information, can be associated with variations of specific features as a step towards a more generalized graphic comprehensibility measure.

2. Requirements in specifications and guides can be made less arbitrary by basing them on performance data.

Background

Current Status

In a recent comprehensive survey of technical manual comprehension, Curran (1977) concluded that:

> Little is known of the variables making up illustrations of various kinds and their relationship to the comprehension of that illustration. The guidance which is offered technical illustrators is for the most part intuitive; virtually, no empirical evidence is available.

There have, of course, been serious efforts to control characteristics of artwork in technical manuals to facilitate the transfer of information to the user. At least two major approaches can be cited.

The first approach is to implement an entire philosophy of how technical information is best presented. This is done through a set of procurement documents detailing the characteristics of the manual and often the processes by which the product is to be achieved. Examples are the Functionally Oriented Maintenance Manuals (FOMM), Fully Proceduralized Job Performance Aids (FPJPA), NAVAIR's Work Package concept, and the Army's Integrated Technical Documentation and Training (ITDT) program. Artwork requirements, often quite detailed, are developed on the basis of general experience, opinion, aesthetic considerations, past practice, reactions against past practice, and reasoning from the overall philosophy. Once the requirements are set forth in procurement documents, technical manuals are procured in conformance with them, and it is nearly impossible to investigate the impact on user performance of systematically varying the more arbitrary aspects of the requirements.

The second approach is represented by several recent studies aimed at relating (1) personnel characteristics such as test scores, rating, reading ability, and experience level, (2) characteristics of the task and the work environment, and (3) optimum modes and formats of data presentation. Recent work sponsored by the Navy Technical Information Presentation Program (NTIPP) provides the beginnings of a model by which the best type of graphic presentation can be selected for a given set of personnel, task, and environmental factors. This approach thus far has been concerned only with the choice of overall type of format. Having recommended, for example, an exploded view of an assembly, it makes no recommendations about features of the drawing itself that may make it easy or difficult to use.

Both of these are positive and important approaches in that they focus on tailoring technical information to match the user's characteristics, needs, and work environment. The present NTIPP-sponsored study, however, is believed to be the first to employ the detailed analysis and objective validation needed to address the problem of establishing requirements for procuring technical information or for objectively measuring the effectiveness of a particular illustration in supporting job performance.

A great deal of technical artwork is controlled by MIL-STD-100 (Engineering Drawing Practices). For economic reasons, preparers of technical manuals are encouraged to use or adapt engineering drawings, since removing extraneous material from existing drawings is less costly than producing new artwork expressly designed for the maintainer or operator. Because of a lack of the type of research represented by the present study, it is not clear that drawings designed to meet the needs of designers and builders are optimal for maintainers and operators, or to what degree and in what ways they are suboptimal. Casual examination of engineering drawings suggests several ways to improve such drawings for maintainer or operator use. Without empirical data on the effects of using current engineering drawing practices to produce artwork to support Navy technician performance, it is impossible to estimate long run cost/benefit ratios as an alternative to immediate cost savings in artwork production.

Guiding Assumptions

To provide an orientation for the development of specific studies of the interaction between a user and graphically presented data, the following principles or assumptions were formulated:

1. At certain points in the user's overall sequence of maintenance or operator actions, the user refers to graphic presentations, using currently available data (entry information) to begin a search (which may be simple or complex) for needed data (target information).

2. Certain identifiable characteristics of arrangement, labeling, referencing, and drawing practices can influence the efficiency of the search. The particular combination of factors contributing to an efficient search will depend on the entry information and the target information. Graphic presentations designed for one type of search will not necessarily be most efficient for another type.

3. In some cases, the beginning and end points of the information search are relatively easy to identify. Early research should focus on such cases, both to generate knowledge about them and to provide insights into methodology for less obvious and more complex user activities.

4. The user is generally not aware of the details of the data extraction process or of the factors that optimize or degrade it. The user's opinion about good and bad artwork can suggest clues for further investigation, but only direct performance measurement should be considered conclusive. The user may become aware of the search process if it becomes unusually difficult or time-consuming, but even then the needed improvements may not be obvious. The user's attention is not focused on the data extraction process itself, nor should it be; an efficient search for data will be as short, automatic, and unintrusive as possible.

5. Even if an illustrator were inclined to consider the search chain from entry information to target information, the most effective combination of characteristics is not always obvious.

6. Aesthetic considerations alone will not guarantee optimal usefulness and may sometimes result in degrading use. It may be necessary to violate aesthetic principles to optimize information search. For example, it may be most beneficial to user performance to get a great deal of information on a single drawing, even though the drawing looks cluttered.

7. **The comprehension or usefulness of a graphic presentation is not a** property of the presentation alone, but depends on what information is being sought from it at a particular moment. It reflects a relationship between the characteristics of the graphic presentation and the task being performed at that moment. Therefore, an index of usability or comprehensibility that does not take the intended use into account is seriously deficient.

Definition of a Specific Problem for Study

Two important assumptions are (1) that an illustration's intended use is critical in evaluating its usefulness, and (2) that the evaluation must be made in terms of measures of user performance. Because of these, certain interesting types of graphics are almost automatically excluded. For example, complex cognitive tasks (e.g., troubleshooting) and the illustrations that support them (e.g., schematics, block diagrams) were not considered amenable at this time to a fine-grained objective study. It is expected that the type of research represented by the present study will suggest ways of objectively studying these other important graphic types and the behaviors associated with them.

Location and identification of parts, however, were judged to be highly suitable user activities for the present study for the following reasons:

1. They are common activities among technical manual users.

2. They are supported by a number of different types of drawings; for example, isometric drawings, cross-sectional views, exploded views, circuit-board drawings, and control-panel drawings.

3. Elements of the drawings that are intended to support this type of search, such as callouts and zones, are obvious. Varying these elements for experimental purposes is not difficult.

4. Advice and requirements relating to these elements are not always consistent, and sometimes appear to derive from considerations of aesthetics and contractor convenience rather than effectiveness and user convenience.

5. Apparent violations of human factors considerations and even common sense are not difficult to find in recent technical manuals.

6. The user's information search task can be easily and realistically simulated with experimental controls.

Even though the present study has been limited to part location and identification, the scope of questions that might be asked is still very broad and includes the following:

1. Should numbered callouts be in sequence? What price in efficiency is paid if they are not? Are there cases where numerical sequence is unimportant?

2. **What is the maximum number of callouts that should appear on a** drawing? Do number callouts and nomenclature callouts differ in this respect?

3. What is the trade-off between having nomenclature callouts on the drawing versus putting the nomenclature in a table keyed to number callouts?

4. When reference designators are used as callouts, are they less discriminable than nomenclature or numbers, and therefore harder for a user to find quickly?

5. Do graphic devices such as circling the numbers or using large, bold type help the user to scan more effectively?

6. Should leaders (the line connecting the callout to the part) or arrows be short so that the callout is close to the part it identifies, or is scanning aided if the leaders are extended so that the callouts are arranged in straight lines?

7. If alphanumeric zones are used, what zone size is most effective?

8. Should the zone reference be keyed to the center of the part, the callout, or the arrowhead?

9. Zone designators on engineering drawings use the lower right corner as the origin and run backwards from the normal reading direction (right to left and bottom to top). Does this degrade search performance?

There are, of course, additional questions concerning the interaction of the various factors with each other and with the type of search being performed. Some of the above questions were addressed in the present study. To limit the scope of the present study, however, reference designators were not studied, and zones were represented only minimally to collect information for the design of a future study.

Three common types of information search related to part location and identification were simulated in this study:

1. A part is cited by callout number in a procedure, explanation, or description: Find the part in the drawing.

2. A part is cited by nomenclature in a procedure, explanation, or description: Find the part in the drawing.

3. A part location in a drawing is known (for instance, by recognizing its physical appearance): Find its nomenclature.

Examples of the Problem Today

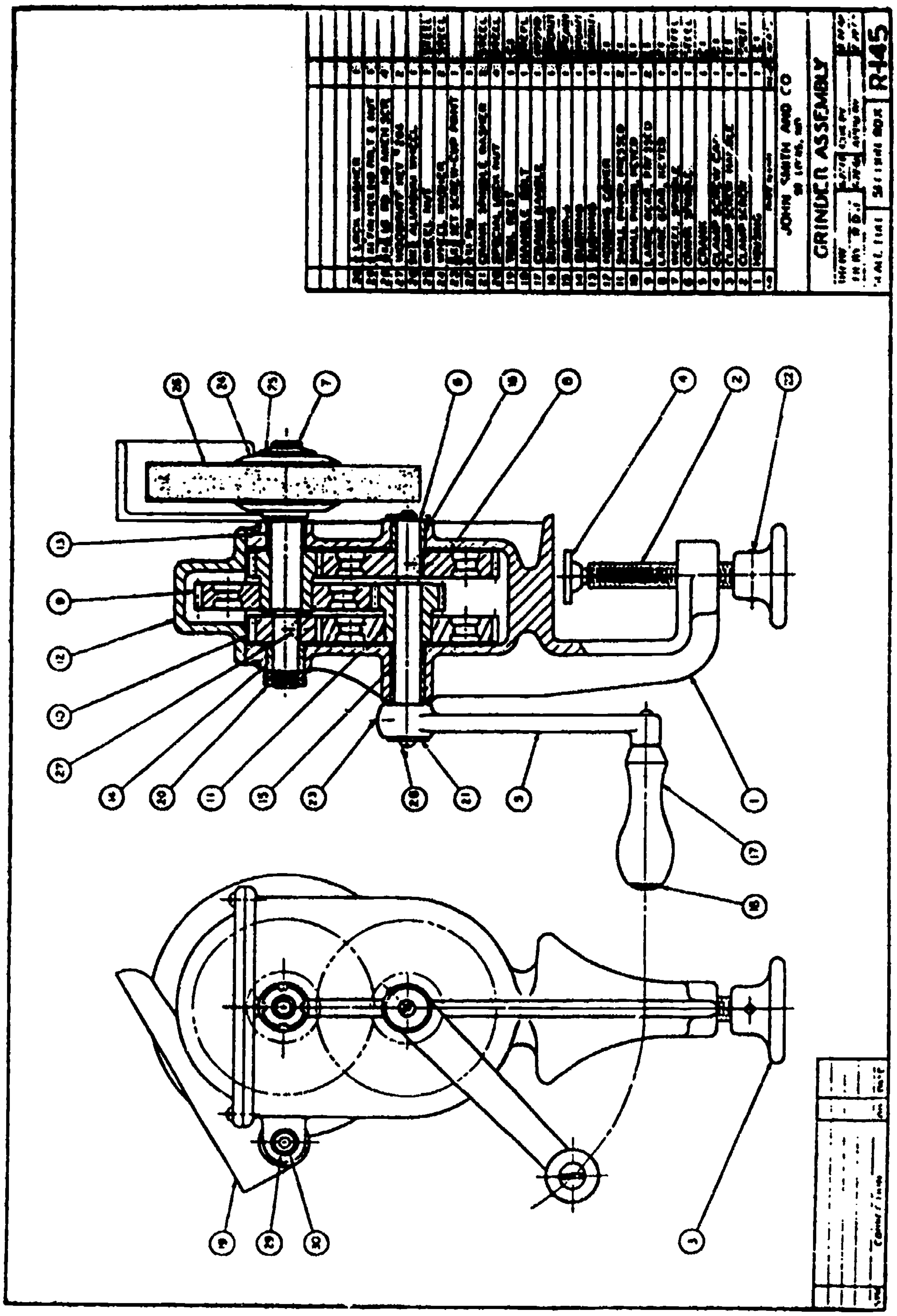
The proper use of callouts and zones to aid the user may seem so simple and intuitive that some readers may doubt that a problem really exists. It is appropriate, therefore, to present examples of practices currently prescribed and employed in technical illustrations. First, examples are presented from textbooks, manuals, and military specifications and handbooks whose function is to guide in the production of technical artwork. Second, examples are taken from technical documents already in use in the Navy. It should be kept in mind that not all of these examples represent practices that always degrade performance; one of the major points in the present approach is that features contributing to usability will differ depending on how the illustration is to be used.

Figure 1, an illustration from a mechanical drawing textbook (Giesecke, Mitchell, Spencer, & Hill, 1974, p. 419), is intended as an example of a correctly produced cross-sectional view and is a type of engineering drawing frequently reproduced "as is" in maintenance manuals. Its lack of numerical sequence in the placement of callouts is common in such drawings. An intuitive recommendation, corroborated by this experiment, is that finding information by means of callouts would be much more efficient if the callouts were in numerical sequence.

Figure 2, found in another illustrating guidebook (French, Svensen, Helsel, & Urbanick, 1974, p. 494), is perhaps an even more severe violation of the same principle. Depending on the particular callout number selected, it may take a frustratingly long time to locate a particular number on the drawing. This is a good example of the need to consider the intended use of the drawing. If the user enters the drawing with the name of the part and his goal is to find the location, then the parts list should probably be in alphabetical order and the callouts should be in numerical order. This task is made maximally difficult by the arrangement shown, because a random search is necessary for both the part name and the callout. If the task is to find the name of a part given its location or physical appearance, then the drawing is acceptable, since the callouts do not have to be searched and ordering the parts list by callout number is helpful.

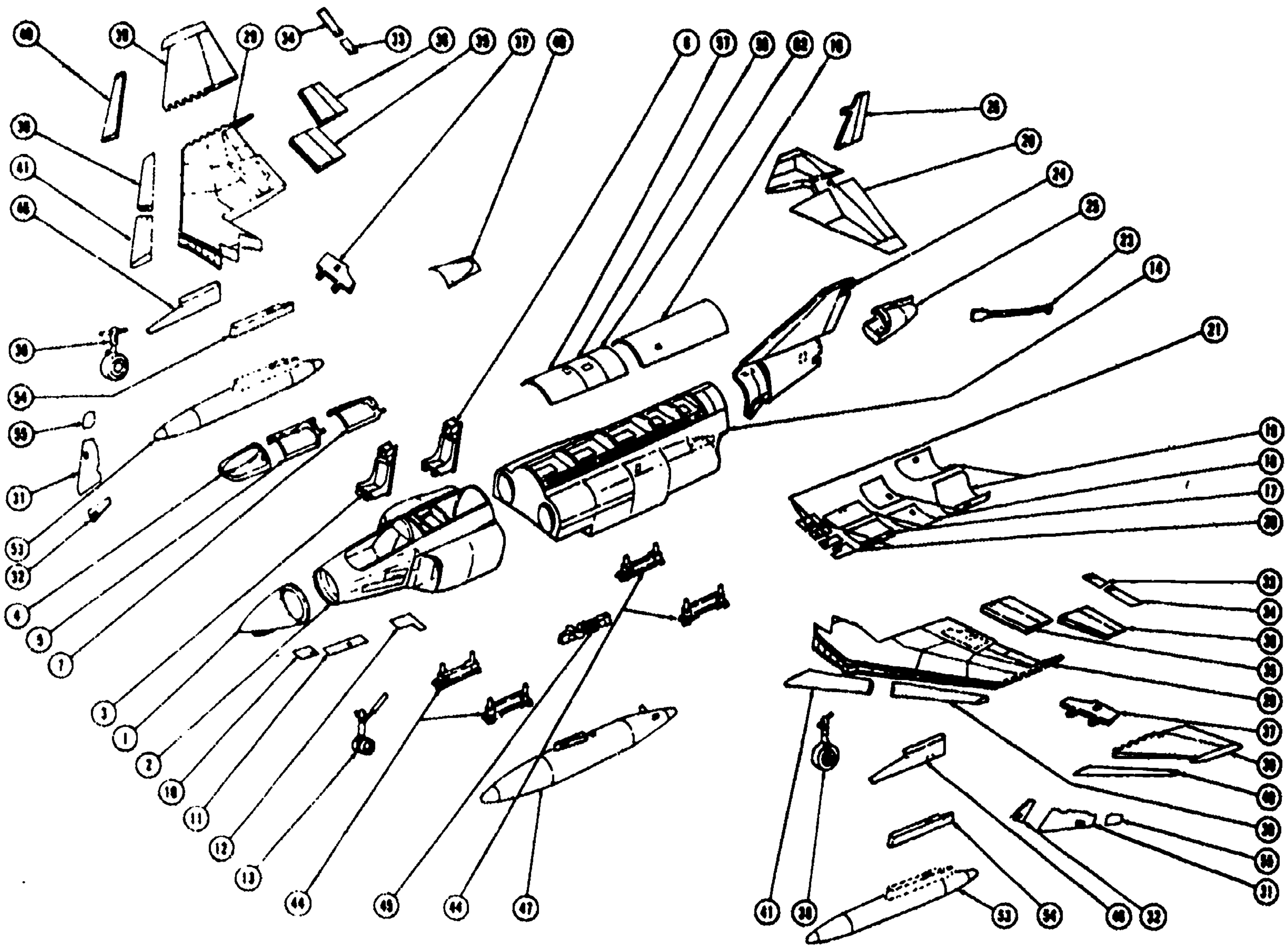
Civilian illustrating guides are not alone in providing questionable recommendations. A new DoD publication, Technical Manual Writing Handbook (1977), contains the "wrong-right" examples shown here as Figure 3. The message of these examples is a warning against extending leaders (the lines connecting the numbers or nomenclatures to the parts) to obtain a simpler scanning pattern. Although there is no evidence that user performance is aided by the "right" approach or degraded by the "wrong" one, no mention is made in the handbook of arranging callouts in sequence, which turns out to be a much more powerful variable in increasing scanning efficiency than length of leaders. Such misplaced emphasis apparently occurs because aesthetic considerations prevail in the absence of hard evidence about the factors that actually enhance usability.

Figure 4 is taken from a writing guide (Post & Price, 1974) that was prepared under contract for the Naval Sea Systems Command but was never used officially for TM acquisition. Because of the small number of callouts in the example, the lack of numerical sequence would probably cause little deterioration in performance, but a principle is illustrated that would be detrimental when applied in other circumstances. For example, a technical



(Excerpted from Giesecke, Mitchell, Spencer, and Hill, "Technical Drawing," Copyright 1974, Macmillan Publishing Co., Inc.)

Figure 1. Cross-sectional view from a mechanical drawing textbook with callouts numbered nonsequentially.



1 Radome
2 Forward fuselage
3 Pilot seat
4 Windshield
5 Forward canopy
6 Radar operation seat
7 Aft canopy
10 Nose landing gear door forward
11 Nose landing gear door aft
12 Hydraulic compartment access door
13 Nose landing gear shock strut
14 Center fuselage
16 Fuel tank door
17 Engine access door
18 Engine access door
19 Engine access door
20 Engine access door
21 Auxiliary engine air door
23 Arresting hook
24 Aft fuselage
25 Tail cone
26 Rudder
28 Stabilator
29 Center section wing
30. Leading edge flap
31. Main landing gear strut door
32. Main landing gear inboard door
33. Inboard spoiler
34 Outboard spoiler
35 Flap
36. Aileron
37 Speed brake
38. Main landing gear shock strut
39. Outer wing
40. Leading edge flap, outboard
41 Leading edge flap, inboard
44. Missile rack
45. Bomb rack
46. Missile pylon
47. External center-line fuel
49. Data link access door
53. External wing fuel tank
54. External wing fuel tank pylon
55. Landing gear door, outboard
56. Boom IFR receptacle access door
57. Fuel cell access door
62. Fuel cell access door

(Excerpted from French, Svensen, Helsel, and Urbanick, "Mechanical Drawing." Copyright 1948, McGraw-Hill, Inc.)

Figure 2. An exploded view from a mechanical drawing textbook in which both callout numbers and table items tend to increase the difficulty of its use.

When alining numbers with each other, don't overdo it. The example below left demonstrates a misplaced effort at good paste-up layout. Keeping the numbers even requires arrows much too long. The example below right demonstrates good paste-up layout.

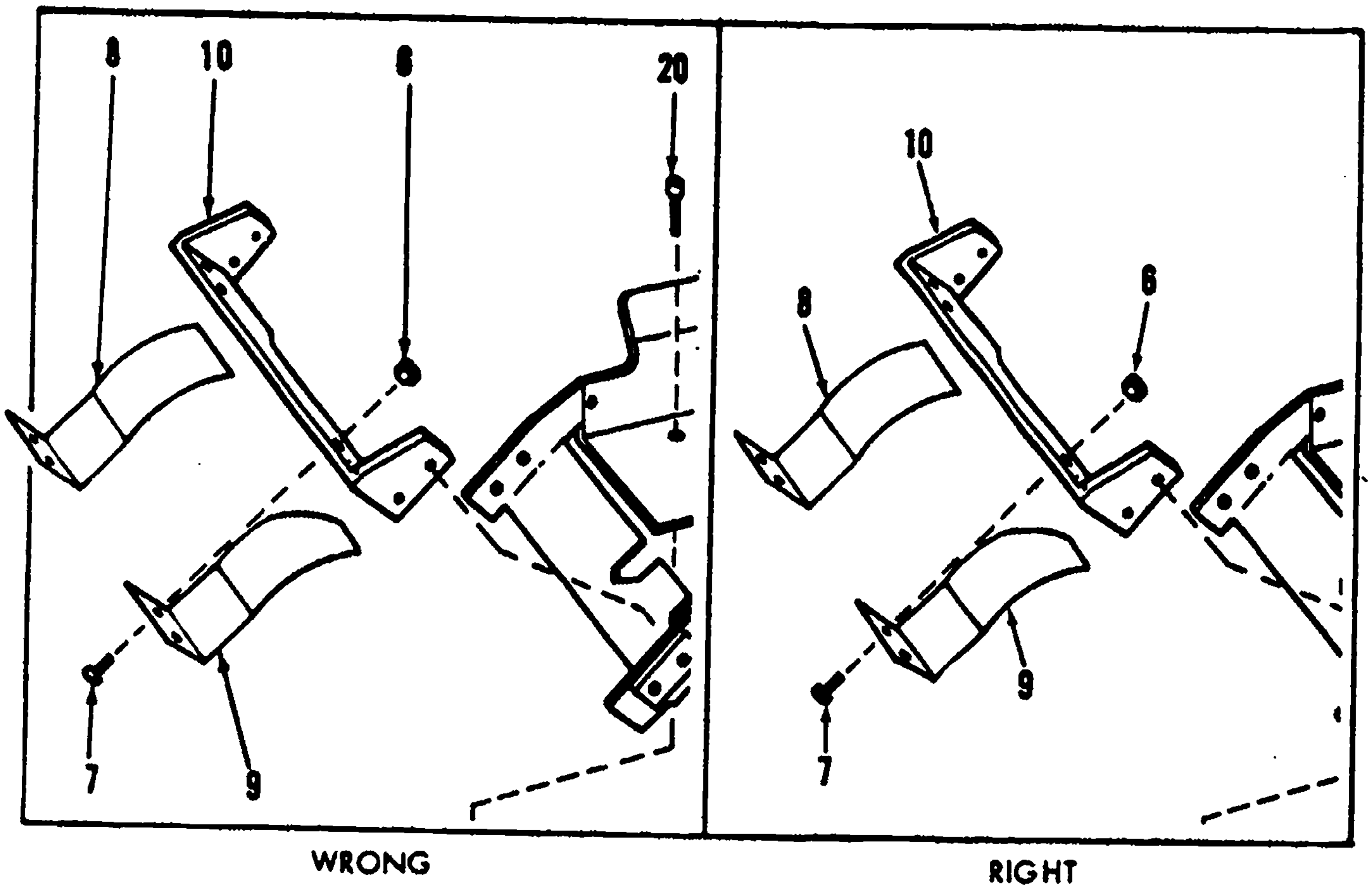


Figure 3. Example of a questionable recommendation in a military style guide.

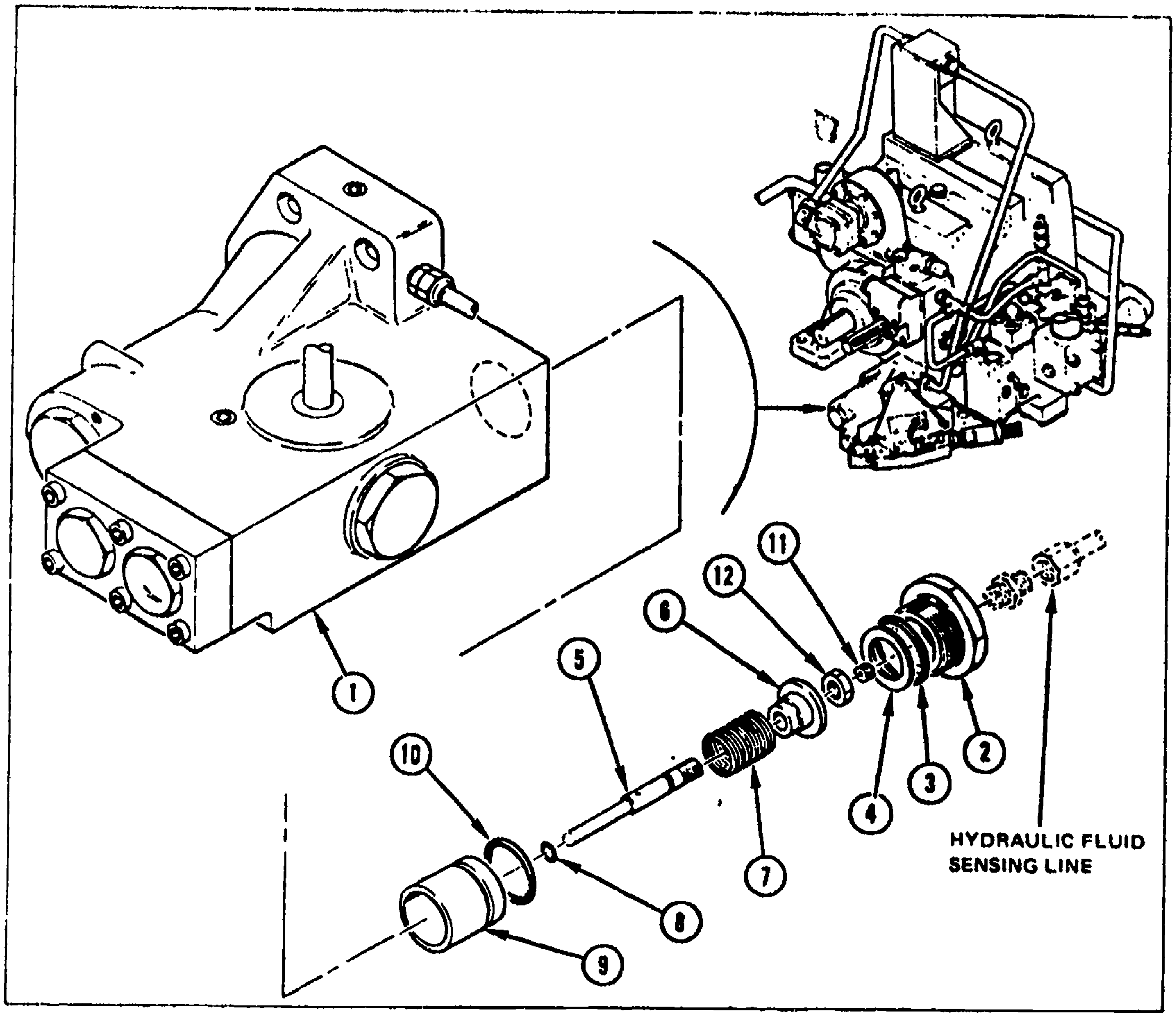


Figure 4. An illustration from a military guide book with callout numbers not in sequence.

illustrator (particularly a novice, who is most likely to be using such guides), in following the manual's recommendations, might be very careful to avoid the use of long leaders, which may or may not be detrimental to the user, and pay no attention to the ordering of callouts, which seriously affects search behavior.

A military publication that also offers acceptable examples of "good" and "bad" graphic practices (Figures 5a and 5b) is NAVAIR's Technical Manual Preparation Guide (1975). Figure 5b is an interesting instance in which rigid adherence to a clockwise sequence of numbers might best be abandoned. Part 27 is actually joined with part 13, and probably should follow part 13 in sequence. Therefore, rather than slavishly following the "clockwise" rule, the callouts can be kept in sequence and at the same time show the actual interrelationship of the parts along the center (axis) line, as shown in Figure 5c.

The technique of arranging callouts in sequence is not a new development. It is, in fact, prescribed by Military Specification MIL-M-38784A (1975), which contains DoD-wide requirements for technical manual style and format. The specification states, "Index [callout] numbers for each separate figure shall start with Arabic number 1 and continue consecutively. Sequence shall be from top to bottom or clockwise, when possible." This requirement is weakened, however, when the specification states, "Item numbers on exploded views used to show assembly/disassembly shall be in disassembly order." In cases where the callout numbers are searched, even when the purpose of the drawing is to aid assembly or disassembly, sequential ordering would appear to be in the best interests of the user. The only exception might be in simple drawings with few callouts, where the callout number sequence is the <u>only</u> device used to indicate assembly or disassembly order.

MIL-M-38784A states that leader lines "shall be uniform, short, and straight as possible." However, this "cosmetic" characteristic was tested in the present experiment (the condition referred to herein as "extending") and showed no conclusive effect on performance. Again, aesthetic considerations, rather than knowledge of effects on performance, seem to be the basis of requirements in the military specification.

Another military specification, MIL-M-15071G, deals with content requirements for Navy technical manuals. Despite the fact that it requires conformance with MIL-M-38784A, its examples do not conform, as indicated by Figure 6. It states, as do other sources, that parts in an exploded view shall be arranged in "correct relative disassembly position." It says nothing directly about callout arrangement, but the implication of Figure 6 is clear. No consideration is given to aiding the user's search.

A major question addressed in this experiment is the number of callouts that may be used on a given illustration and the interactions of other factors with that number. Post and Price (1974), under the heading "Pictorials Practices," recommended that callouts be limited to seven or less. No distinction was made between nomenclature and number callouts. This surely does not mean, for example, that on an 11 x 17 inch drawing there should be no

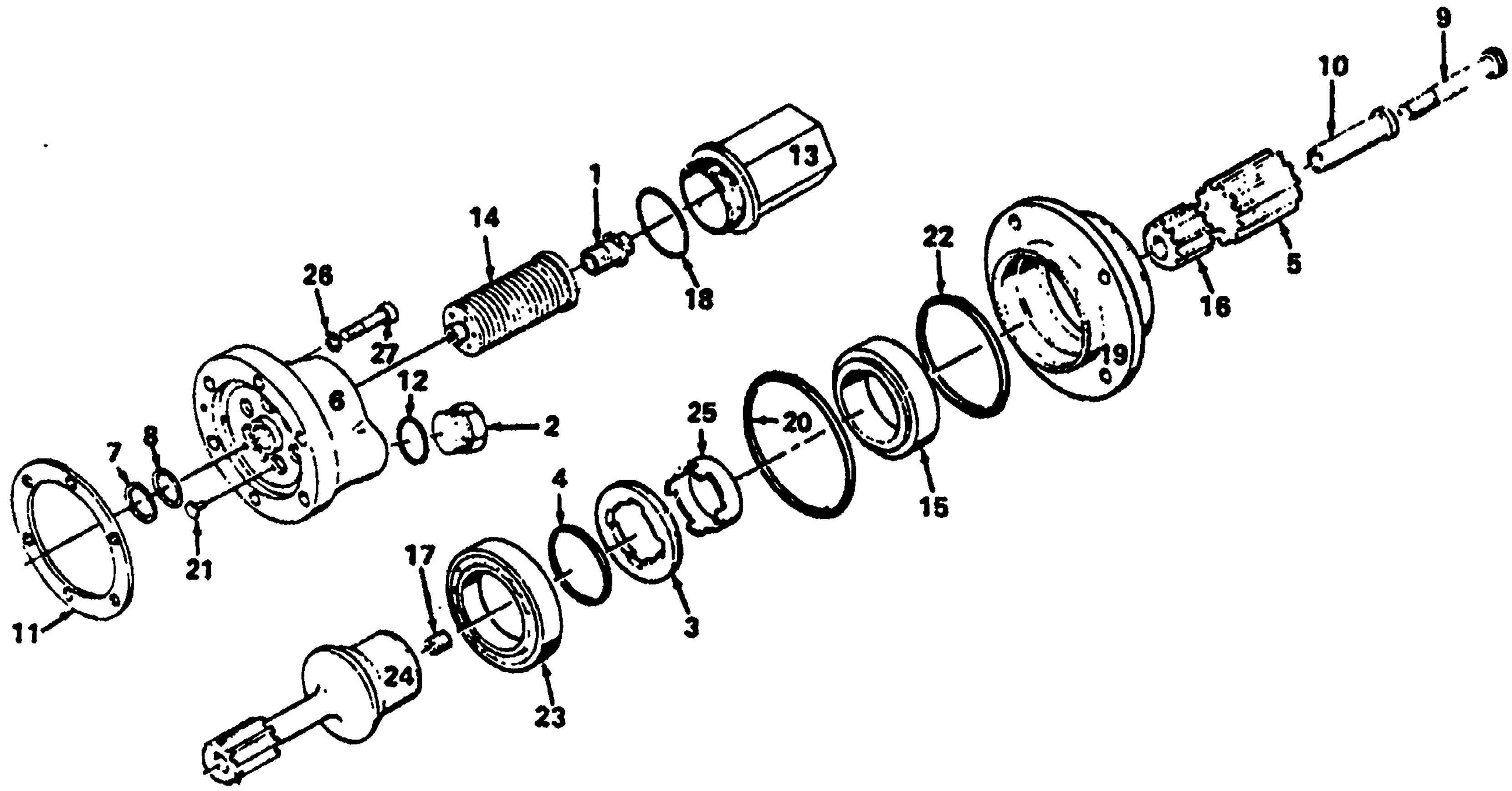


Figure 5a. *Illustration with Poor Callout Placement*

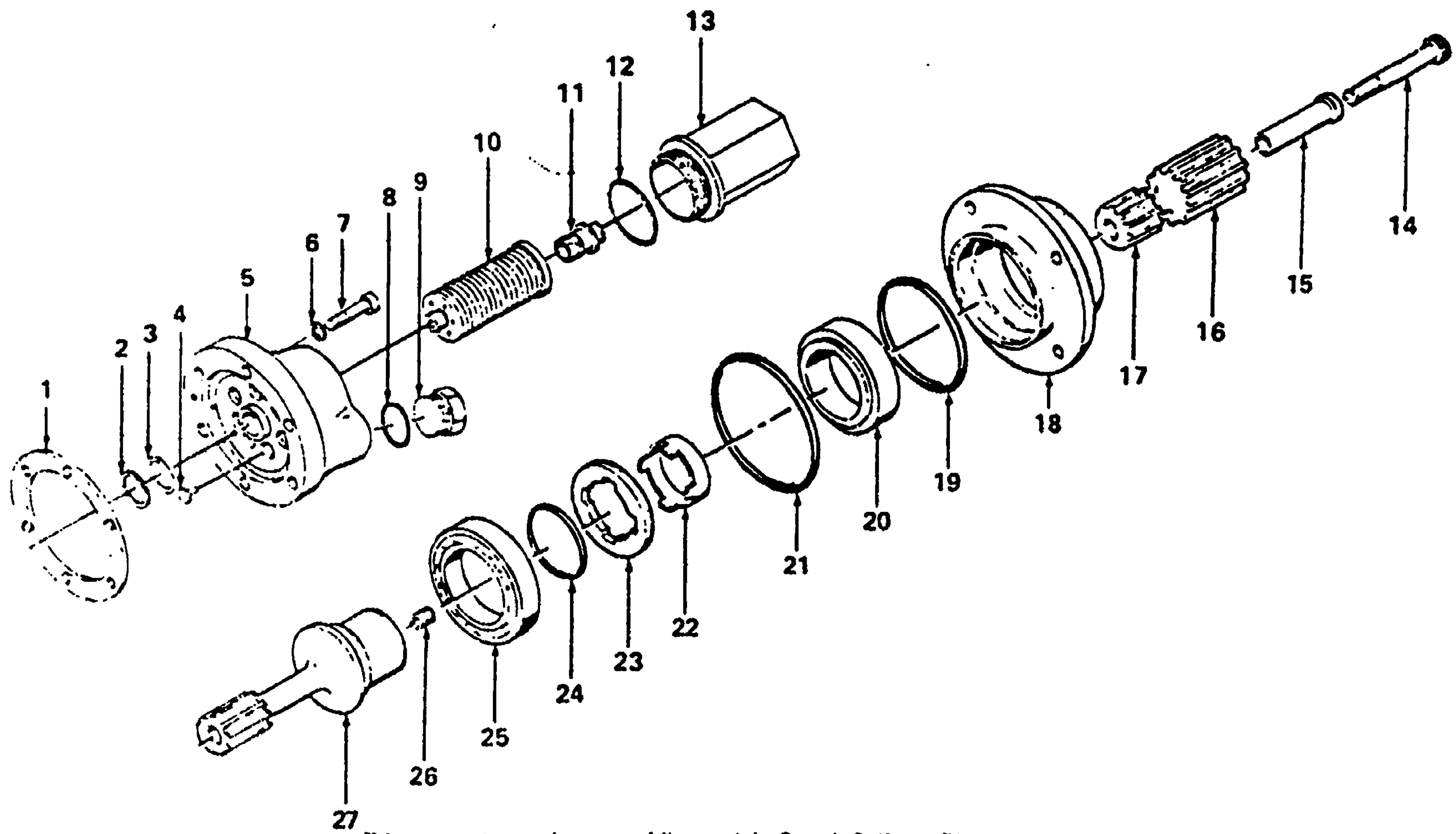


Figure 5b. *Locator View with Good Callout Placement*

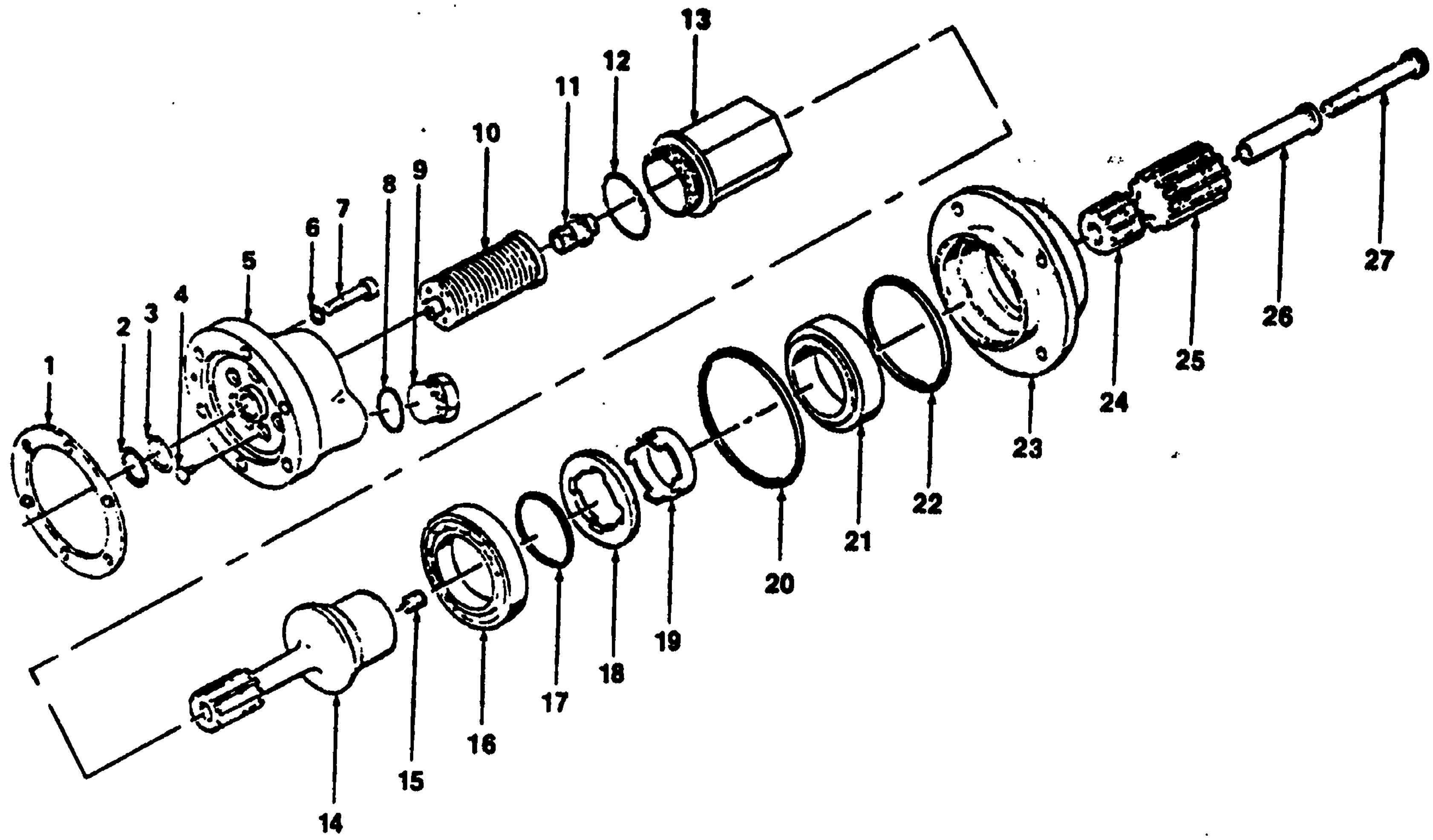


Figure 5c. Improvement of Figure 5b by adding an axis line and renumbering callouts.

Index No.	Zone	Part Number	Qty	*Reference Designation
1	3B	Commutator Cover	...	MP3
2	3C	Socket-Head Capscrew	8	MP18
3	2D	Wiper	...	MP17
4	..	Not Used		..
5	1A	Commutator Shaft	...	MP13
6	3C	Hex Nut	2	MP8
7	3C	Washer	...	MP19
8	1A	Key	...	MP14
9	3C	Socket-Head Capscrew	4	MP20
10**	1C	Brush	2	MP9
11**	1C	Brush	4	MP11
12**	2D	Brush	6	MP10
13	2D	Wiper Spacer	...	MP16
14	1A	Bearing Cap	..	MP12
15	2D	Commutator Hub	...	MP2
16	2A	Ball Bearing	...	MP4
17, 18	2A	Bearing Spacer Assembly	...	MP15
19	2A	Ball Bearing	...	MP4
20	2D	Insulator	...	MP21
21	2D	Printed Circuit	...	MP22
22	2D	Rear Cover	..	MP23
23	1D	Flat-Head Screw	2	MP24

* Reference Designation Prefix is 12A17A1A1 unless otherwise stated

**Items to be segregated when removed for replacement at reassembly
Refer to Parts List for procurement information

Note: Sample arrangement only. Size and legibility do not conform to minimum specification requirements. Supplementary data normally appears on an apron.

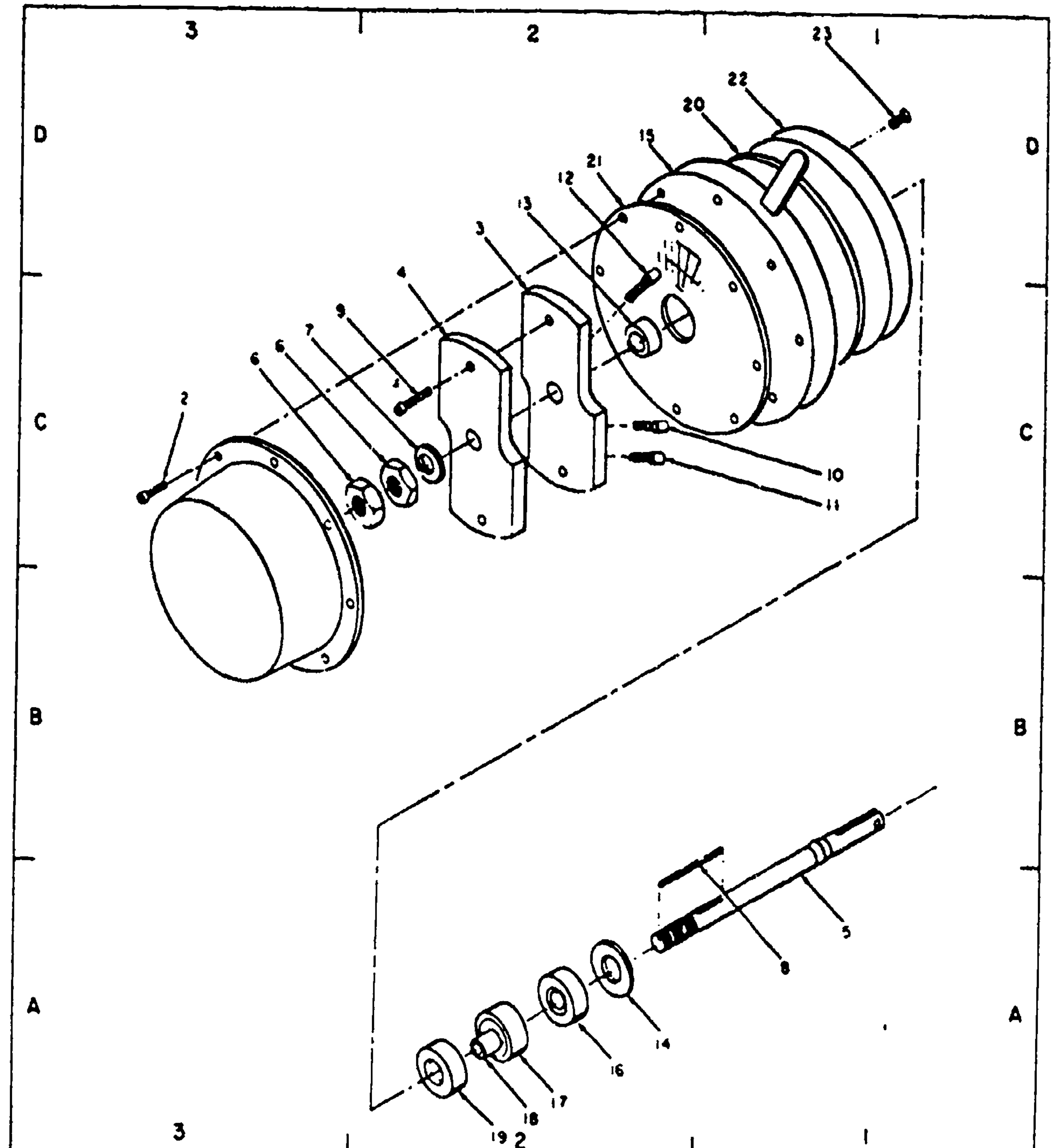


Figure 6. Sample illustration with callouts apparently arranged in disassembly order rather than in numerical sequence.

more than seven number callouts. What it does mean, however, is not clear. It seems to recommend that no more than seven callouts appear in a grid of some unspecified size. A similar warning appears in the NAVAIR guide, which states that there should be no more than five number callouts in any 1-square-inch area. It further specifies that "...the average maximum number of callouts within a 7 x 9 inch area should be 70." This requirement is badly stated, since it would allow dense packing of callouts in some drawings as long as there were other drawings with low callout density to bring down the average. Whatever the origin and validity of these numerical limits, the authors of these documents seem to believe that they are better than no guidelines at all. Research should be directed at establishing specific limits based on user performance. These limits would probably differ depending on whether callouts were numbers, nomenclature, reference designators, or combinations of these types. At this time, no one really knows the maximum density of callouts with which a user can easily contend.

Very little searching is required to locate violations of the sort discussed above in virtually any type of Navy technical manual for any type of system or equipment. Appendix A contains six examples of the stimuli actually used in this experiment, all of which are variations of two actual technical manual illustrations, both of which were considered unacceptable for various reasons. Appendix B contains seven additional examples (reproduced actual size) from different kinds of Navy manuals.

Figure B-1 is included for two reasons. First, its callout arrangement, while not as difficult to use as some others, is not in sequence, and callout numbers jump from one drawing in the figure to another and back again. If there are several drawings on a page, then callouts should probably be arranged in numerical order in each of the drawings, even if the drawings are intimately interrelated. Second, Figure B-1 is quite similar to the original of the cross-sectional drawing used as an experimental stimulus in the present study, including the hand lettering of numbers and nomenclature. With as few callouts as are found on this drawing, the use of nomenclature in the callouts seems appropriate. With relatively few callouts, if the user's task is to identify a part, then it is probably more efficient if the nomenclature is in the callout than if it is in an accompanying table.

Figure B-2 is from a different section of the same manual as Figure B-1. It is legitimate to use such drawings, according to MIL-M-38784A, "provided they meet the reproducible [sic] requirements herein. Borders, title blocks, manufacturer's notes and irrelevant material shall be removed." In the case of Figure B-2 there is severe "information compression" caused by reducing the size of the original drawing, there is no organized callout sequence, and the manufacturer's detailed information was not removed. Any one of these factors should have been cause for rejection of the drawing, but this illustration and many others similar to it were accepted, at least for the preliminary manual.

Figure B-3 is taken from a sonar systems manual dealing with towed-array hoists. It is included to illustrate a common problem, that of undersized print in the callouts. Another problem in Figure B-3 is that the leader lines are drawn in such a way that they might be confused with the lines of the

drawing. Again, there is a lack of systematic organization of the numbers on the drawing. It is exceptionally difficult to get started on this drawing, that is, to locate callout number 1.

Figure B-4 is taken from an ordnance publication. The drawing includes essentially three different kinds of callouts. Some callout numbers are circled, some are not, and some are "stacked," which many sources discourage (with no supporting empirical evidence). Common sense alone would suggest greater consistency in the physical characteristics of callouts on a drawing.

Figure B-5 is taken from an engineering system technical manual (NAVSHIPS 0951-010-0010). It suffers from the common faults of failing to order callouts systematically and of requiring the reader to jump back and forth between the figure's drawings to follow the numerical sequence.

The fact that Figures B-1 through B-5 were taken from different types of Navy manuals indicates the widespread nature of the problems being addressed in this study and, consequently, the need for corrective action.

The Naval Air Systems Command has generally been much more consistent than other SYSCOMs, from the standpoint of aiding the user, in the illustration of its manuals. This tendency has been advanced by its "Work Package" concept, which makes use of a larger number of small, special-purpose illustrations rather than a smaller number of large, complex, general-purpose ones. (The Army's Integrated Technical Documentation and Training (ITDT) program is fostering the same trend.) Even NAVAIR technical information, however, is not totally free of the types of problems discussed above. Figure B-6 illustrates the random order of callouts in a work package. The accompanying procedural steps illustrate what may be the cause of this problem in many cases: The callouts are ordered as they are referred to in the procedure. This is common practice in both military and commercial drawings that support procedural steps, but it does the user no good to have the parts so numbered because the task does not involve searching the steps for callout numbers. Upon encountering a callout number in a procedural step, the user must search the drawing, which is where the numbers ought to be in sequence. Performance would not be degraded in the least if the callout numbers were out of order in the procedural steps, but would be improved significantly if they were in order on the drawing.

Figure B-7, from NAVSHIPS 91921(A), Instruction Book for Radar Set AN/SPS-10, was considered so unsuitable for maintenance use that it was rejected as a stimulus for the present experiment. In particular, note the two 1-inch squares drawn on the illustration. As mentioned earlier, various sources advise limiting callouts to about five to seven per 1-square-inch area, but one of the squares on Figure B-7 has 12 and the other has 11. Requirements to limit callout density are obviously needed, but they should be based on performance data, particularly since research to generate such data is neither difficult nor expensive.

The matter of zones (coordinates), although receiving minimal attention in the present study, provides interesting examples of the dearth of good information on how to aid the user in locating parts. For example, MIL-M-15071G requires zoning as follows:

> Diagrams shall be divided into equally spaced horizontal zones (ordinates) designated A, B, etc., from bottom to top along the outside left and right borders. Diagrams shall be divided into equally spaced vertical zones (abscissa) designated 1, 2, 3, etc., from right to left along the outside top and bottom borders. The zone size shall be as needed to clearly locate referenced points.

Note that the required order of numbers and letters along the axes is the reverse of normal reading. Engineering drawings have zones arranged in this fashion, and the requirement in MIL-M-15071G is apparently intended to eliminate the need to redraw the axes. The benefit is to the producer of the drawing, not to the user. Zone size is left largely to the discretion of the illustrator. It should not be difficult to develop data for a functional relationship between part density, zone size, and search performance to formulate intelligent requirements.

WS-10759 (NAVORD Specification/Purchase Description for Ordnance Publications), a specification frequently invoked by NAVSEA for weapon system manuals, requires zones as follows:

> Diagrams shall be divided into three horizontal zones (ordinates) with the lower zone designated A, the middle zone designated B, and the upper zone designated C outside the left and right borders. Diagrams shall be divided into vertical zones (abscissa) 4-3/4 inches wide final size, designated 1, 2, 3, etc., from right to left outside the top and bottom border.

The zones are again "backwards," but this time they are required to be quite large.

As a final example of the range of variation, Figure 7 is taken from a Functionally Oriented Maintenance Manual (FOMM), NAVSEA 0967-LP-603-8030. FOMM manuals are based on an explicit user-oriented approach. In this case the effort to aid the user resulted in "overkill," thus increasing the difficulty of the user's search. The double indexing of zones to achieve 0.2-inch resolution results in a cumbersome zone designation system (e.g., D.E/7.5). First, this places an unnecessary load on the immediate memory of the user and leads to an increased chance of reading errors. Second, this degree of precision is not necessary to locate the parts quickly. Third, users are unable to track horizontally or vertically on the page to this degree of precision without an overlay grid or a straightedge. The result is that users quickly learn to read and remember only the major coordinates (e.g., D-7) and to locate the part accordingly. Users should not have to learn to ignore information that was put there to help them.

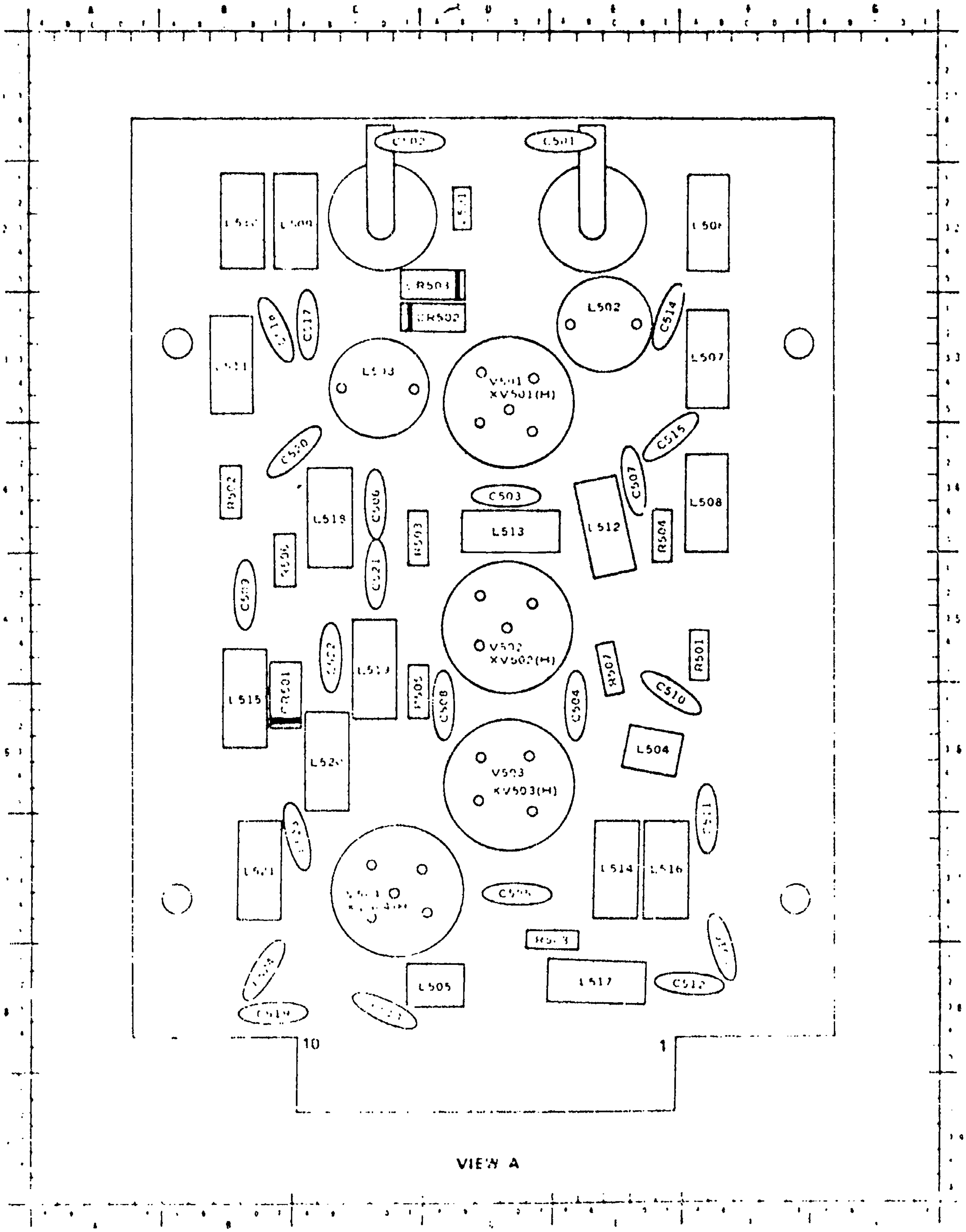


Figure 7. Technical manual illustration with fine-grained zones.

It is clear from these examples that there is little empirically based information to guide illustrators in enhancing user performance, and intuition is an unreliable guide. Even conscious efforts to aid the user sometimes misfire. The necessary data would often not be difficult to obtain from the standpoint of methodology, but would require a large program of painstaking research. The present study is an effort to inspire such a program.

METHOD

The general approach was to identify tasks that closely simulate what a technician does when he is using a graphic presentation to get needed information. These tasks were restricted to location and identification of parts by use of callouts with and without parts lists, and, to a minor extent, zones. As described below, variations in number, content, and arrangement of callouts were incorporated into drawings, were presented to subjects using five different types of task instructions, and were evaluated according to the time required for the specified information search.

Illustration Types

Stimulus variations were incorporated into two basic drawings taken from Navy technical manuals: a cross-sectional view (C/S) of an electric motor, taken from the AN/SPS-58 Radar Maintenance Manual (NAVSHIPS 0967-320-4040), and an exploded view (E/V) of a chart drive. These are typical of drawings found in all types of Navy technical manuals. The originals were modified to produce the experimental variations, examples of which are reproduced in Appendix A. All types of variation are illustrated in these examples. The original drawings appear as Figures A-2 and A-6, except that Figure A-2 was hand lettered in its original form.

Variations of the C/S are not directly comparable to those of the E/V. In particular, the C/S as originally drawn had nomenclature callouts, which were retained in some of the variations. Because of the placement of callouts on the E/V, nomenclature callouts were completely impractical.

Number of Callouts

The number of callouts on a drawing was varied in four steps: 10, 27, 44, and 62. This variable was applied in identical fashion to both the C/S and the E/V.

Arrangement and Content of Callouts

There were 13 variations in the arrangement and content of callouts. The variations were based on two types of drawings (cross-sectional and exploded views), three methods of labeling (number, nomenclature, or both), and three treatment variables (callout order, number circling, and leader extension). Each of the treatment variables consisted of two levels:

1. Order: Callouts could be arranged sequentially (SEQ) or at random (RAN).

2. Circling: Numbers could be circled (C) to distinguish them from other elements of the drawing, or could be not circled (NC).

3. Extension: Callout leaders could be extended (E) to the drawing's edge to line up the callouts and make scanning easier, or have nonextended (NE) leaders of more uniform length. In the E conditions, callouts that could

not be brought to the edge due to space limitations were lined up diagonally near the center of the drawing.

Of the 13 variations, 5 were applied to the C/S:

1. Nomenclature only (NOMEN).

2. Numbers in sequence (NUM-SEQ).

3. Numbers in random order (NUM-RAN).

4. Nomenclature with numbers in sequence (N/N-SEQ).

5. Nomenclature with numbers in random order (N/N-RAN).

The remaining eight variations (illustrated in Figures A-1, A-3, A-4, and A-5) used only number callouts:

1. Sequential, circled, extended (SEQ/C/E).

2. Sequential, circled, not extended (SEQ/C/NE).

3. Sequential, not circled, extended (SEQ/NC/E).

4. Sequential, not circled, not extended (SEQ/NC/NE).

5. Random, circled, extended (RAN/C/E).

6. Random, circled, not extended (RAN/C/NE).

7. Random, not circled, extended (RAN/NC/E).

8. Random, not circled, not extended (RAN/NC/NE).

Subject Tasks

Five subject tasks were defined that simulate user behavior in the work environment. Each is best described by its corresponding instruction to the subject:

1. "Point to the part with callout number X." (Callout appears in a procedure or equipment description referencing a figure.)

2. "Point to the part called Y." (Nomenclature appears in a procedure or description referencing a figure.)

3. "Tell me the nomenclature of the part marked in red." (Physical appearance or location of the part is known, and the nomenclature is sought.)

4. "Use the zone system to point to the part with callout number X." (Same situation as in Task 1.)

5. **"Use the zone system to point to the part called Y." (Same situation as Task 2.)**

The zone system refers to the alphanumeric coordinates appearing on the exploded view. Given the callout number or nomenclature, the subject must use a table to find the coordinates of the part.

Test Items

Figure 8 shows all possible combinations of task and stimulus variations. Each of these combinations defines a single test item that could potentially be administered to experimental subjects. A subset of 160 of these, indicated in Figure 8 by diagonal lines, was actually used in the experiment.

Task 1 NOMEN would have necessitated the use of a table, and did not appear to lend itself to sufficiently interesting comparisons. For Tasks 4 and 5, which involved the use of the zone system, the intent was to develop some preliminary information rather than to be exhaustive. It was decided that the zone system would be useful only in situations where there was a relatively large number of callouts in random order, so only these test items were used.

Before each test item, the subject was given (1) background information to simulate what a user would ordinarily know about a drawing, (2) entry information, and (3) his task. Thus, in a typical test item, the subject would be told, "The next drawing is the exploded view with callouts that have numbers out of order. Point to the part with callout number 28. Go." The subject would then turn to the drawing and find the required part.

Selection of Target Information

For each test item, a part was selected whose location or identity was the target of the information search. Targets were selected with three primary criteria:

1. Responding to a test item should not aid the subject on a later item.

2. Targets were selected equally from all areas of the drawings.

3. Items differing only by the number of callouts were assigned targets that were not identical but that, to the extent possible, were in the same area of the drawing.

Accompanying Tables

In Tasks 2, 3, 4, and 5, the subject often required information that was not part of the callout. Tables (parts lists) were used to supply the missing information. In Tasks 2 and 3 the table provided the bridge between callout number and nomenclature, and in Tasks 4 and 5 the table provided zone information. All tables were in the same format. The number of items in each table corresponded to the number of callouts on the drawing, and the items

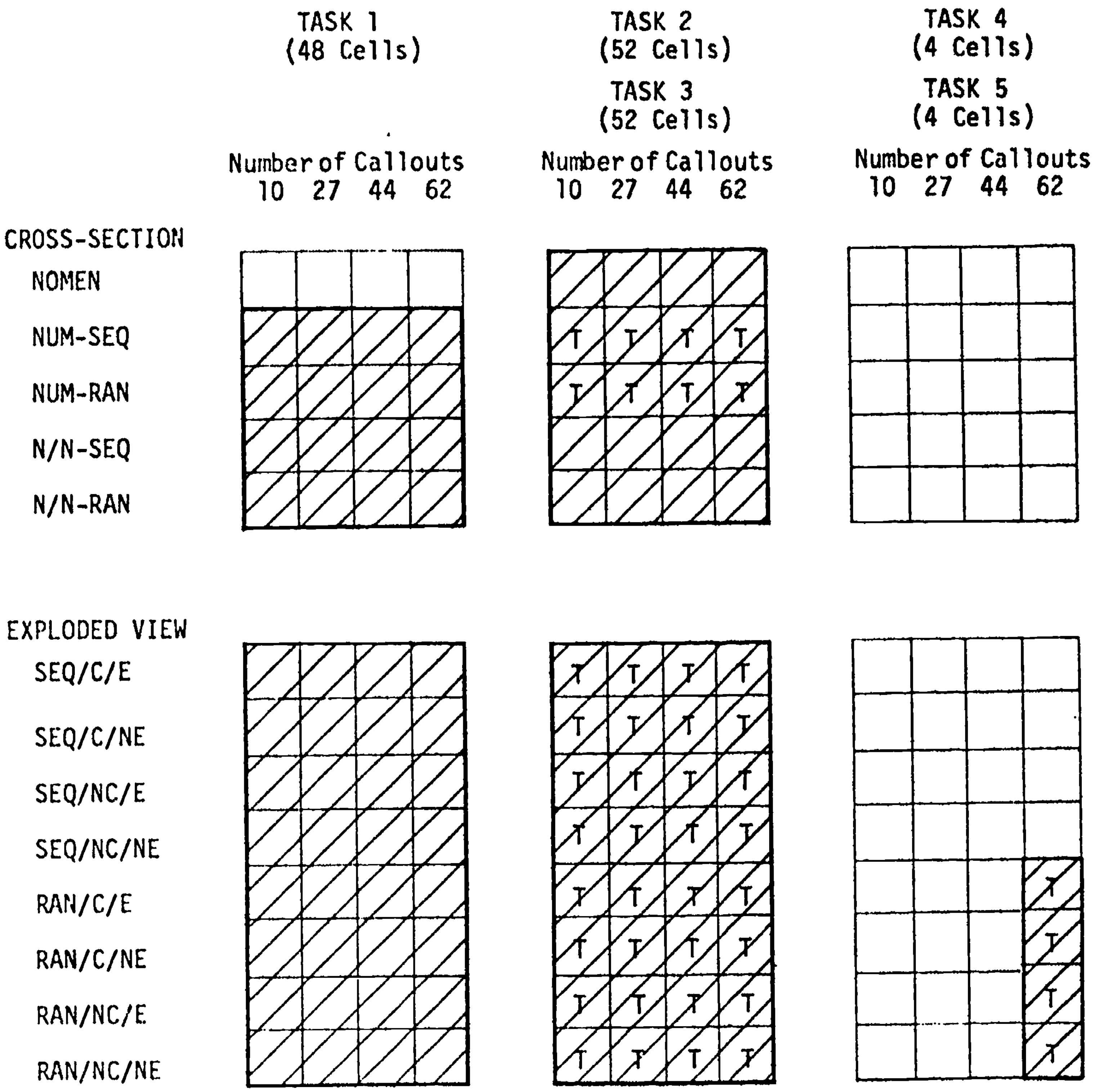


Figure 8. Diagram of experimental design: stimulus-task combinations used in study are cross-hatched; T indicates use of parts list table required.

were listed in callout number sequence. The tables were therefore efficient when entered by callout number, and less efficient when entered by nomenclature. No task required the subject to enter the table by zone designation. Test items that required the use of a table are indicated in Figure 8.

Groups

Preliminary trials using the stimulus materials indicated that to administer all 160 test items in one session would have been too fatiguing for the subject. Therefore, the 160 test items were divided into four groups of 40, with the various levels of each independent variable represented equally in each group. One group of 40 test items was administered to each subject.

Other Materials

In addition to the drawings, which were bound in scrambled order for the subjects' use, there was a corresponding set of item description sheets to be read to the subjects in connection with each drawing. Before the test items were administered, each subject completed a data sheet that included rate, educational level, Navy schools attended, and shipboard experience. Standard explanations and instructions were read to the subjects. Since the experimenter's task was extremely tedious, all materials were organized for easy administration.

Dependent Variable

The response variable was the time in seconds (recorded to the nearest tenth) required to complete each information search. After reading the item description sheet, the experimenter said, "Go," whereupon the subject turned to the next drawing and the timing began. Timing continued until the subject either pointed at a part in the drawing or began to speak his response, as required. If the response was not correct, then the experimenter said, "That's not it," and resumed timing.

Subjects

Subjects were 243 Navy enlisted men in three different rating groups: Sonar Technician (ST), Gunner's Mate (GM), and Boiler Technician (BT). To examine the effect of different experience levels on performance, 40 ST "strikers" (seamen and below who are to be rated as STs upon completion of sonar "A" school) were tested. Table 1 compares these four groups on a variety of characteristics. The major factors noticed in this comparison are (1) the expected dissimilarity between the experienced and inexperienced STs, (2) the somewhat greater similarity between STs and BTs than between STs and GMs, and (3) the expected lower levels of education (on the average) for both GMs and BTs as compared to STs.

Subjects were well-motivated and cooperative. Subjects' spontaneous comments indicated that the stimulus variations were obvious enough that the subjects could relate potential outcomes of the study to their own job tasks.

Table 1

Summary of Subject Characteristics

Rating Group/ Experience[a]	N	Average Time in Navy (yrs)	Education (Percentages)			Rates (Percentages)						
			No H.S. Deg	H.S. Deg	Some Col	E-1	E-2	E-3	E-4	E-5	E-6	E-7
Sonar Technicians (High Exper.)	144	3.56	1	74	25	--	--	8	45	33	13	1
Sonar Strikers (Low Exper.)[b]	40	.33	5	82	13	33	12	55	--	--	--	--
Gunner's Mates	31	2.21	26	68	6	--	16	52	32	--	--	--
Boiler Technicians	28	4.57	11	75	14	--	--	7	43	36	14	--

[a]Two different experience levels compared for Sonar rating only.

[b]These personnel were waiting for their Sonar "A" School to begin; none were rated as STs.

Data Analysis

The selection of an approach to data analysis must take into account the following considerations:

1. A cursory examination of the data indicated that the distributions are markedly skewed, as would be expected of time data of this sort.

2. Means and variances of the distributions appear to be correlated substantially.

3. Because the cells of the design are divided among four groups of subjects, the observations may not be statistically independent.

4. It is necessary to make numerous tests of significance on the data, pooling observations from the same subjects and from different subjects in various combinations.

Under these circumstances, the following was regarded as the most reasonable approach:

1. Use appropriate nonparametric tests. There is evidence that the correlations among observations are negligible; the use of nonparametric tests appears justified. The Mann-Whitney U test for the two-sample case and the Kruskal-Wallis test for the k-sample case were selected because they are the most powerful nonparametric tests of their respective null hypotheses.

2. Be conservative in selecting a significance level. When numerous tests are performed, it is expected that some of the "significant" differences will actually be due to chance. This is less likely if the significance level is conservative. Consider using $p < .001$ as the lowest acceptable level.

3. Mathematically transform the scores to reduce the skewness and render the data more amenable to a standard analysis of variance. The reciprocal of time scores (which may be interpreted as a measure of speed) is often used with response time data for this purpose.

Test Item Distributions

Appendix C contains descriptive data on the distribution of scores for each of the 160 test items. The tables in this appendix show the highest and lowest scores, the quartiles, the range, the interquartile range, the number of subjects, and the group to which the item was administered. These distributions are displayed in groups of four. For Tasks 1, 2, and 3 the distributions for the four number-of-callout steps are shown together; thus, the effect of increasing the number of callouts can be seen directly. For Tasks 4 and 5 only four test items were administered; these are shown together (Tables C-39 and C-40). For each set of four test items, the result of the Kruskal-Wallis k-sample test is shown. Numerous other significance tests were performed and are cited in the text as appropriate.

In general, a large proportion of the Kruskal-Wallis and Mann-Whitney tests indicated highly significant distribution differences among the various conditions. Since most of the significant differenc· were in the expected direction and were well beyond the .001 level, it appears reasonable to accept this as evidence that the factors that were varied did influence performance (search time).

In addition, six analyses of variance were performed on the reciprocals of the time scores (Tasks 1, 2, and 3 for E/V and C/S separately). The E/V analyses used five factors (number of callouts, sequence, circling, extending, and subject group), and the C/S analyses used four (number of callouts, sequence, presence of nomenclature, and subject group). Interaction tables were examined and compared with the results of the nonparametric tests.

Sources of Extraneous Variability

At a number of points in the data analysis, unexpected and inconsistent findings occurred. Examination of the stimulus materials disclosed two major causes for these unsystematic results: (1) the position of the target information in the table (for Task 2 only) with resulting differential search times, and (2) one or more perceptual phenomena (such as figure-ground effects or generalized scanning strategies) that are systematic across subjects but are unexplained so far.

Table Search Time

In Task 2 the subject must find the part name in a table, note the callout number associated with the part, and then locate that callout number on the drawing. The time recorded for each subject was measured from the moment he began to search the table to the moment he pointed to the correct part on the drawing. The total time, therefore, includes two separate activities: looking up the part name in the table and searching for the callout number on the drawing. For task realism these two activities were not experimentally separated in the administration of Task 2. Further, the start of the

[redacted]
reliable end points for the measurement of the time interval.

A separate study was conducted to determine the average time required to locate items at varying "depths" in a table. Using a 62-item table, 16 part names were selected at depths varying from item number 2 to item number 58. Part names that might be ambiguous (e.g., "roller mounting plate," "roller mount") were avoided. Subjects were told: "Starting at the top of the table, find the part called the ________ and tell me its callout number." Times were measured from the moment the subject oriented himself to the table until he began to speak the callout number.

The results of this table-search experiment are shown graphically in Figure 9. The darkened circles represent the median times required to locate target items in the table. The line through the data points represents a linear approximation to the data points. Each Task 2 data point was corrected by subtracting from the observed time the average table search time estimated from the linear function derived above. Unless otherwise specified, all comparisons involving Task 2 data that are made below use the corrected times.

Perceptual Processes

The second source of uncontrolled variability is not easily explained and offers no method of correction. These perceptual phenomena were quite systematic across subjects and in no way would have been predicted. Several examples are provided to describe their effects.

Figure D-1 is the cross-sectional view with 44 number callouts in random order. One Task 1 item required that subjects locate and point to the part with callout number 14. Taken in isolation, callout number 14 actually stands out from the callouts surrounding it; that is, once located, it is perceptually prominent. The average time required to locate this item, however, ranged from 7.75 seconds for the STs to 19.35 seconds for GMs, with BTs requiring 13.8 seconds. For each of the three groups, the time was from [illegible] to 13 seconds greater than for a corresponding item on a 62-callout drawing. It is hypothesized that the reason for these unanticipated findings is that a subject searching the drawing of Figure D-1 tends to "leap" from the neighboring callout 23 to callout 3 (or vice versa) and tends not to see number 14.

This phenomenon occurs in a similar fashion in certain tasks with the exploded view. In Figure D-2a, for Task 1, the target item is callout number 28. As with the preceding example, the callout appears in what might be considered a prominent position. Compare this drawing with Figure D-2b, the same drawing but with 62 callouts. It was hypothesized from the outset that, [illegible] things being equal, it would take longer to locate a target item [illegible] callouts than among 44 callouts. The target item on Figure D-2b is [illegible] which appears to be embedded among other numbers and should perhaps [illegible]. The actual findings were the reverse of this [illegible] the three subject groups, it took longer to locate [illegible] callout drawing than it did to locate number 53 on

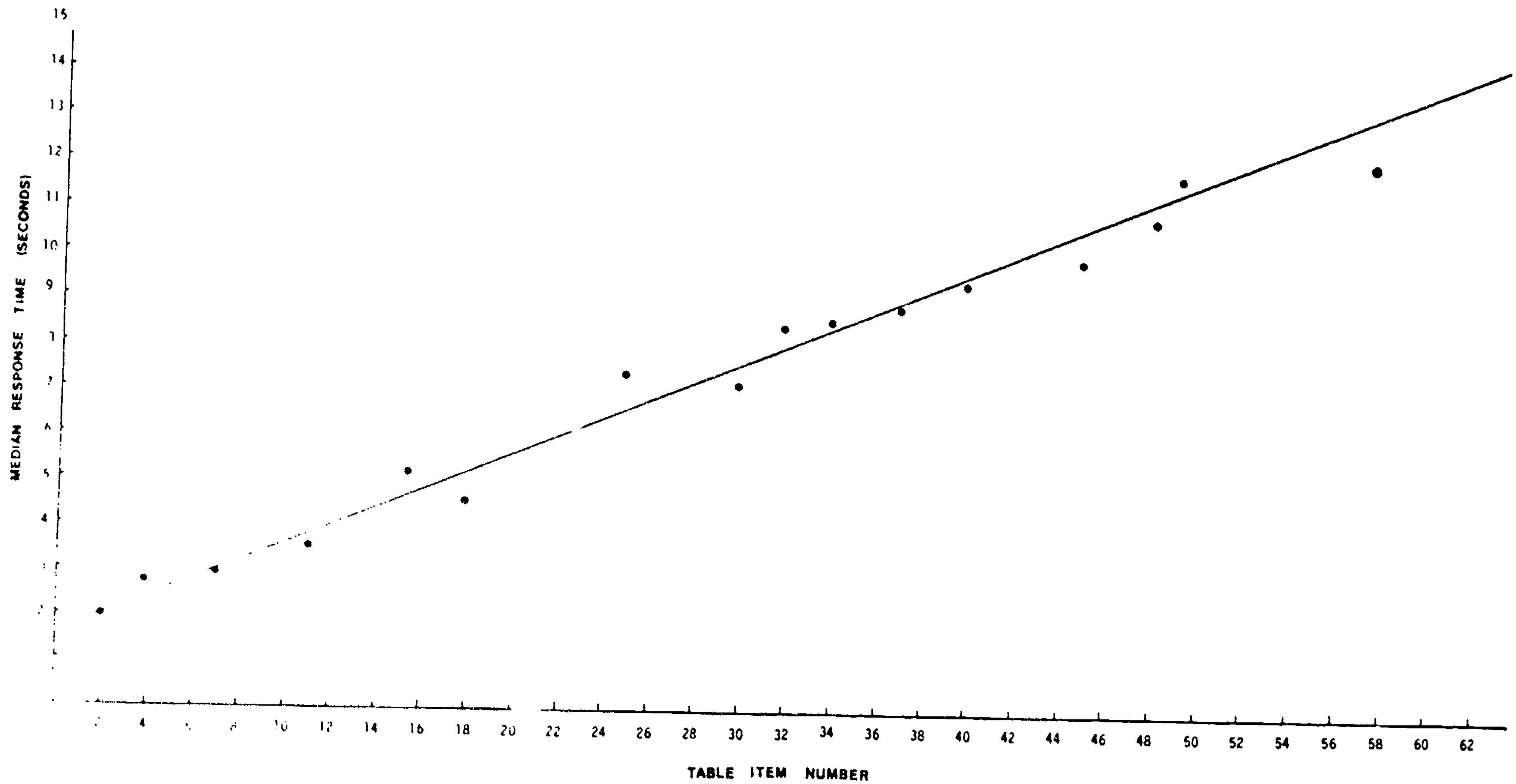


Figure 9. Plot of required search time for items varying in location in a table.

the 62-callout drawing. The median times for the 62-callout condition were 3.50, 7.10, and 8.90 for groups ST, GM, and BT, respectively. For 44 callouts, the corresponding times were 8.50, 15.45, and 11.00. The explanation for the apparent difficulty in locating item number 28 might be similar to that proposed for the cross-sectional view. It may be hypothesized that, when scanning the callouts, a majority of people begin with a left-to-right sequence corresponding to normal reading habit. In Figure D-2a this abruptly becomes a top-to-bottom sequence at the upper right hand corner of the drawing (the location of callout number 28). In making this change of direction, it is hypothesized that subjects tend to "cut the corner" and overlook the target item. On the 62-callout drawing, the number 53 is directly in the line of scan (right-to-left in this case) and is therefore located more easily. The callout arrangement of Figure 2 might alleviate such a problem, and provides one type of stimulus pattern for checking the hypothesis.

A final example of this problem's pervasiveness is illustrated by Figure D-3, the cross-sectional view with both numbers and nomenclature for callouts. In Task 2, the subject is required to search the callouts to locate a part with a specified name. In Figure D-3, the target item is the FAN. The median times required to locate the FAN were 11.75, 29.90, and 36.65 seconds for STs, BTs, and GMs, respectively. Again, it may be supposed that subjects fail to perceive objects outside of a relatively narrow scan path--a scan path that is determined by the physical arrangement of the objects being scanned. In this case, it would appear that the scan path is from item 46 to 58 to 16 to 48 (or the reverse of this order), and that number 30 (tne FAN) is masked by this pattern.

If this explanation is valid, then there is no easy "correction factor" that can be applied to findings resulting from this phenomenon as there was with table-search times. Further, from existing data it is difficult to predetermine which stimuli might be affected by this phenomenon.

Cross-sectional View

The results for the cross-sectional view are presented by subject task. The major findings are (1) that, in certain circumstances, sequential order of number callouts is extremely important, and (2) that user characteristics reflected in Navy ratings influence search times.

Task 1 Findings

In Task 1, the instruction to the subject was to point to the part with a given callout number. For the cross-sectional view this pertains to the conditions in which the callouts are either numbers only or both numbers and nomenclature (with a random and sequential order in each case). Figure 10 illustrates the findings in the condition where callouts are numbers only. Since the GM and BT samples had similar individual profiles for this situation, they were pooled for the purposes of this comparison. In the condition with only 10 callouts, there is virtually no difference in the time required to locate the target information dependent upon either the subject

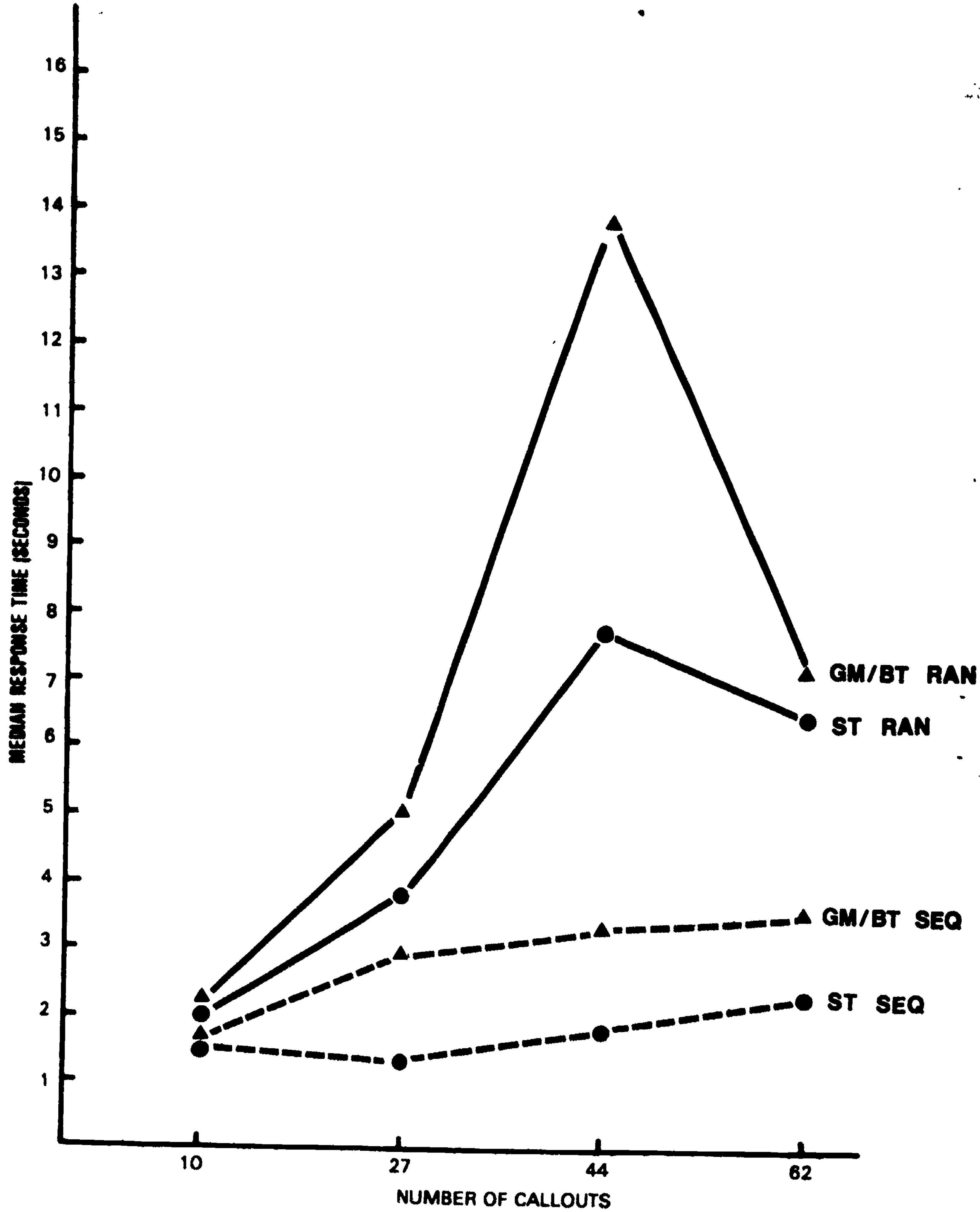


Figure 10. A comparison of Task 1 performance with sequence and random conditions for ST and GM/BT groups combined.

(rating) group or callout order. This result is found in nearly every comparison made, and unless a particular point is to be made with regard to the 10-callout case, it will not be discussed further. The 10-callout case was intended to represent a lower boundary condition--a number of callouts small enough so that other conditions would have little effect--and seems to have functioned adequately for this purpose.

Figure 10 illustrates the overall range of times for the two groups and the two orders, rather than the individual data points. With 27 callouts, a divergence begins to be seen both between sequential and random orders and between the different rating groups. Although the differences here are not statistically significant and probably are of little or no practical significance, there is a tendency (even with as few as 27 callouts) for more time to be required when callouts are in random order than when they are in sequence. The evidence indicates that the break point between acceptable and unacceptable practices (e.g., sequential versus random order) occurs at about 27 callouts.

When searching for information among 44 callouts (and probably fewer, down to some point around 27), the ordering of callouts in sequence becomes more critical. In the case of STs, it takes an average of three to four times as long to find a target item when the callouts are in random order as when they are in sequence. This difference is of high statistical significance and has great practical significance as well. It is also important to note that search time itself is not the only factor involved here. Users might very well become frustrated when unable to find needed information quickly, and either ignore the drawing completely or use it inefficiently. In the 44-callout condition the STs and the GM/BT group differ greatly in the time required to locate the target information. As was pointed out earlier, the particular target item in this case was unexpectedly difficult to locate. Although the target item was identical for all subjects, the average times required to locate the item were 7.75, 13.80, and 19.35 seconds for the ST, BT, and GM groups, respectively. The difference between search times for the GMs and the STs is statistically significant, and the difference for the BTs and the STs approaches significance. These differences can be explained only in terms of differences among subject groups.

With 62 callouts, the BT sample tended to take longer to locate the target information than did the GMs or STs. The search time differences between the combined GM/BT group and the ST group are not significant.

When numbers and nomenclature both appear in the callout, and when the subject is asked to find the part with callout number X, the GM and BT groups tend to take longer than the ST sample, but this difference is probably too small to be of practical significance (e.g., an average of about 3 seconds with 62 callouts). Here, however, a general finding of some importance is that the appearance of nomenclature in the callout does not seriously interfere with the search for a particular callout number. Differences between numbers only and numbers with nomenclature are generally small.

Task 2 Findings

Task 2 required the subject, given the nomenclature, to locate the part on the illustration. This involved searching the drawing directly when the callouts were nomenclature alone or nomenclature with numbers, and searching first a table and then the drawing when the callouts were numbers only. The differences found for Task 2 with numbers only (after subtracting table-search times) are inconsistent. The expected differences between sequential and random orders occur, but little difference was found among rating groups. One exception to this was the unexpectedly long time required for the BT sample to locate the target information in the sequence condition with 62 callouts. That task took the BT group an average of 10.8 seconds, compared with 3.95 and 4.70 seconds for GMs and STs, respectively. With the data available, this difference cannot be explained.

When numbers and nomenclature were both included in the callout, the BT sample required a longer time, on the average, in both the sequential and random conditions, and the GM group required a much longer time in the random condition only. Figure 11 illustrates the profiles for the random condition. Note that, with 62 callouts, the ST group required an average of 11.75 seconds to locate the target information; the BT group, 29.9 seconds, and the GM group, 36.6 seconds. Assuming that these results generalize sufficiently, this is a situation in which consideration of user characteristics must have top priority. Even the ST sample had relatively long response times, and when another group takes three times as long, it is evident that relief is required. At least one of two steps should be taken: (1) ensure that callouts are ordered in sequence, and (2) reduce the number of callouts on the drawing. Again, note that, with as few as 10 callouts (and perhaps even with as many as 27), there is no great problem for any of the user groups sampled even if the callouts are in random order.

Numbers with nomenclature in the callout actually interfered with the task when the task required locating a part by nomenclature. This is in contrast to the reciprocal: Nomenclature did not interfere with locating a part by number. Figure 12 illustrates this situation, giving the ranges of median response times across the three main subject samples. The comparison for 10 callouts shows the two conditions to have a quite short and almost entirely overlapping range. In the 27-callout situation, the picture is unclear, with the ranges appearing unexpectedly large relative to the 10- and 44-callout ranges. A clear pattern emerges for 44 and 62 callouts, however. The ranges for the nomenclature-only condition are relatively short and the times involved are relatively low. The ranges for the nomenclature-plus-number conditions are nonoverlapping with nomenclature only and are considerably higher. This suggests that, if the intended use of the drawing is the location of information on the basis of part nomenclature, then numbers should be omitted. Probably the best arrangement for a Task 2 search, although not directly tested in this experiment, is to use nomenclature only if there are 10 callouts or fewer, and otherwise to use numbers in sequence keyed to an alphabetical table.

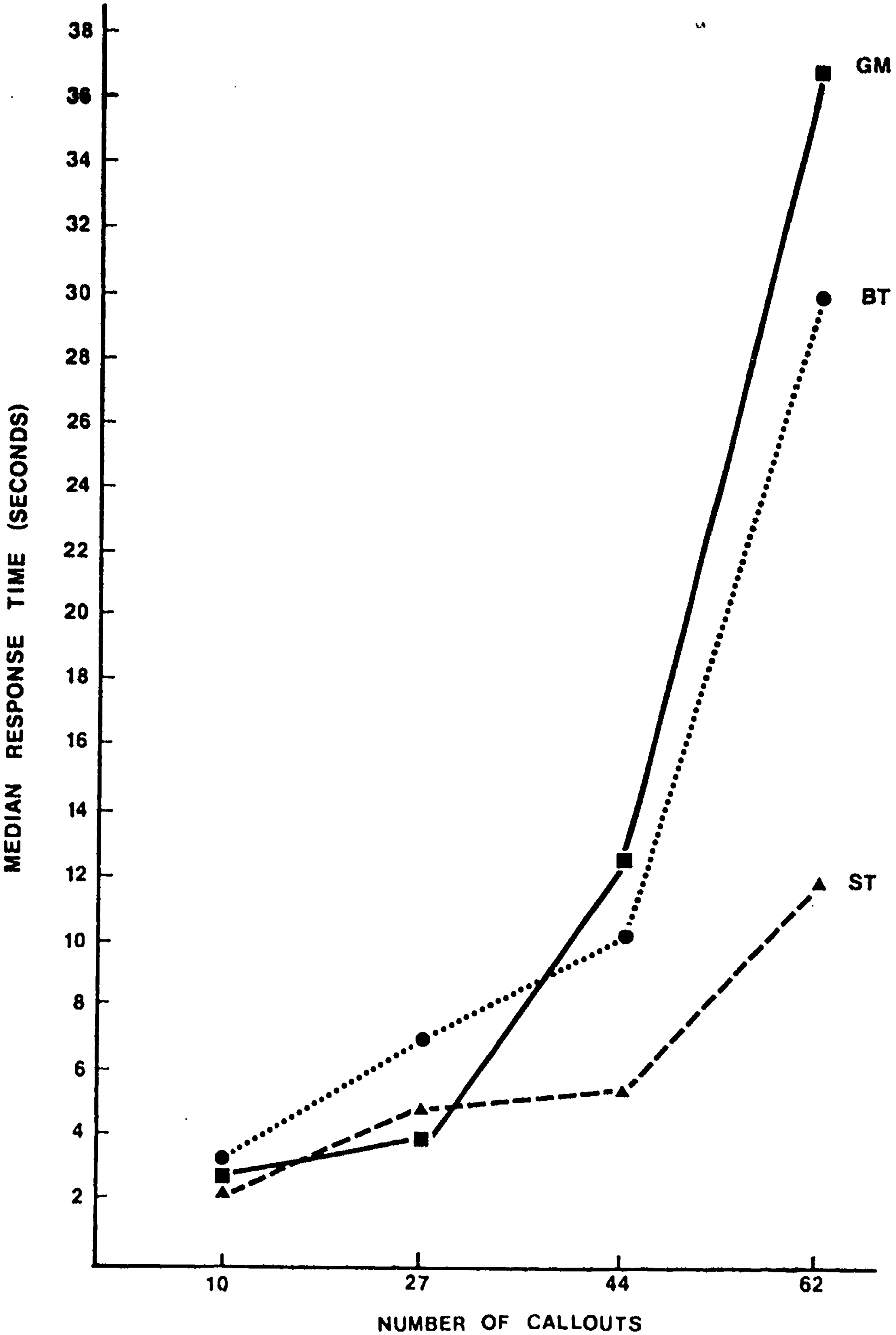


Figure 11. A comparison of Task 2 performance in the random condition among ST, BT, and GM groups.

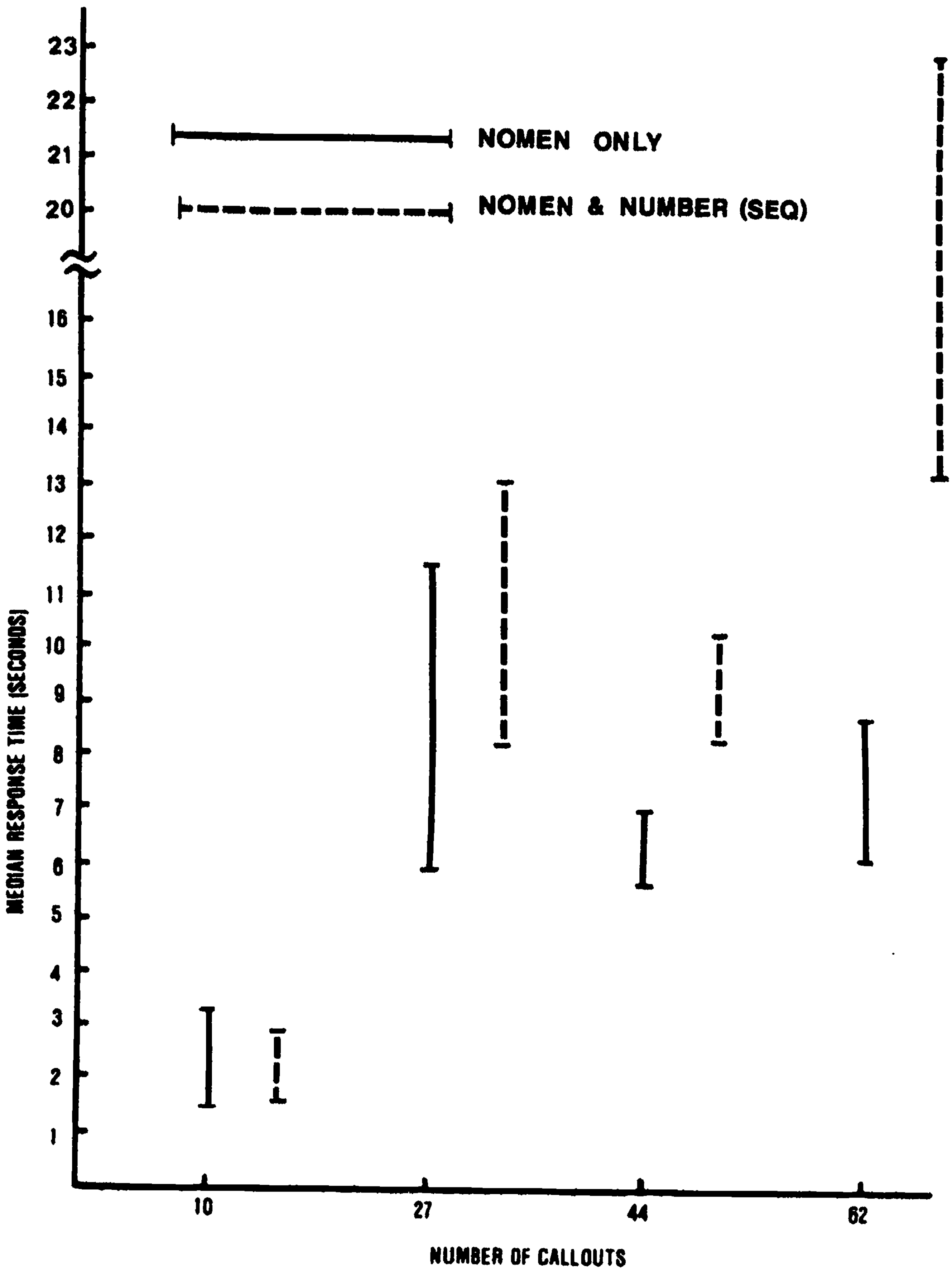


Figure 12. Ranges of median response times given nomenclature only or nomenclature plus numbers in Task 2 for ST, BT, and GM groups combined.

Task 3 Findings

In Task 3 the subject was to tell the name of a part marked in red. As in Task 2, tables were required for some conditions. For these, the subject found the callout number in the drawing and used that number to enter the table. Since the tables were organized according to callout number sequence, the tables were efficiently designed for this type of response, and the times are uniformly short. With 10 callouts there was no difference between having the nomenclature in the callouts and using a separate table. For larger numbers of callouts, there appears to be an advantage to having the nomenclature in the callouts, even when the number of callouts is large. In general, there appears to be some increase in search time as the number of callouts increases from 10 to 27, but not much difference for subsequent increases.

For the conditions in which the nomenclature was contained in the callouts, there were no differences clearly attributable to an increased number of callouts, and no differences were expected. Similarly, in the number-plus-nomenclature conditions, there was no difference in identifying the nomenclature of the marked part when the callouts were in sequential or random order. This finding does not argue for the use of random order of numbers in callouts. As discussed under Task 2 above, if the drawing's only use is to determine the nomenclature of a part whose location is known, then the use of numbers in the callout is unnecessary. If the numbers might have to be used in addition to the nomenclature, then the results from Task 1 and Task 2 responses indicate that the callout numbers should always be in sequence.

Summary of Findings for Cross-sectional View

1. Throughout the analysis of the cross-sectional drawing results, GMs and BTs tended to take longer to find the target information than did the STs. Whether this is a function of aptitude differences or of a mechanical versus electronic orientation is not known, but it clearly points to the fact that optimally designed drawings for different user groups may not be the same.

2. When the number of numerical callouts reaches about 27, their order begins to become important. Search time may increase by a factor of three or four if the callouts are not in sequence. It is recommended that, even with very few callouts, the numbers be organized in sequence so that such organization becomes standard and can be expected by the user.

3. If the intended purpose of a drawing is to locate a part whose callout number is known, then numbers alone or both numbers and nomenclature are equally efficient. If this is the drawing's sole purpose, the inclusion of nomenclature in addition to numbers would increase the drawing's cost without significantly improving its utility.

4. If the intended purpose of a drawing is to locate a part whose nomenclature is known, then the inclusion of numbers in addition to nomenclature will interfere with the task.

5. If the intended purpose of a drawing is to determine the nomenclature of a part whose location is known (Task 3), then there is little to be said regarding any of the variables studied here, except for the order of items in the table. If numbers alone are used in the callouts, then they should be in sequence (for standardization purposes) and the items in the table should be ordered according to callout numbers rather than alphabetically.

Exploded View

The results for random versus sequential order of callouts were quite conclusive, as were those for the cross-sectional view. Circling, extending leaders, and using zones produced mixed and inconclusive findings. Differences between experienced STs and inexperienced ST "strikers" were not significant, but differences were discovered between experienced STs and the GM and BT samples.

Random (RAN) and Sequential (SEQ) Order

The variations imposed upon the exploded view had the form of a 2 x 2 x 2 factorial design. The factors were random versus sequential order, circled versus noncircled numbers, and extended versus nonextended leaders. As expected, the order of the number callouts was again the most powerful variable manipulated in this study.

In virtually every case in which the number of callouts was 27 or greater, the time required to locate a number when callouts were in random order was significantly longer than when callouts were in sequence. For Tasks 1, 2, and 3, within each number-of-callouts step and for each subject group, the SEQ conditions were combined and contrasted with the RAN conditions. Tables 2, 3, and 4 show median response times according to number of callouts and rating group for Tasks 1, 2, and 3, respectively.

Task 1 Findings. For Task 1 ("Point to the part with callout number X"), Table 2 shows that when the numbers are in sequence, the time required to locate a target item is essentially no different when there are 10, 27, 44, or 62 callouts. Figures 13 and 14 illustrate the Task 1 performance of GMs and BTs as compared to STs.[1] The curves for callouts in sequence are nearly horizontal; the differences that are seen are nonsystematic and statistically nonsignificant. The fact that no differences were found for callouts in sequence, even between 10 and 62 callouts, is itself an important finding. Although one might have expected a gradual increase in the time required to locate information as the number of callouts increased, none occurred. The small differences in the profiles are most likely due to experimental error rather than to any differences inherent in the stimuli. Knowing that a coming

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[1]Experienced STs will again be used as the anchor group in these comparisons. Inexperienced ST strikers were sufficiently similar to the experienced group that they will not be discussed further.

Table 2

Task 1, Exploded View, SEQ and RAN
Median Response Times: ST(Hi), ST(Lo), GM, BT

Rating Group	Number of Callouts 10	27	44	62
	Task 1 SEQ			
ST (Hi)	2.00	2.50	2.15	2.10
ST (Lo)	2.38	2.63	2.23	2.03
GM	2.43	3.55	2.85	3.38
BT	3.00	4.60	2.80	2.65
	Task 1 RAN			
ST (Hi)	2.55	3.55	6.80	7.65
ST (Lo)	2.85	4.08	6.48	10.83
GM	3.17	4.40	6.73	11.10
BT	3.15	5.10	10.85	10.95

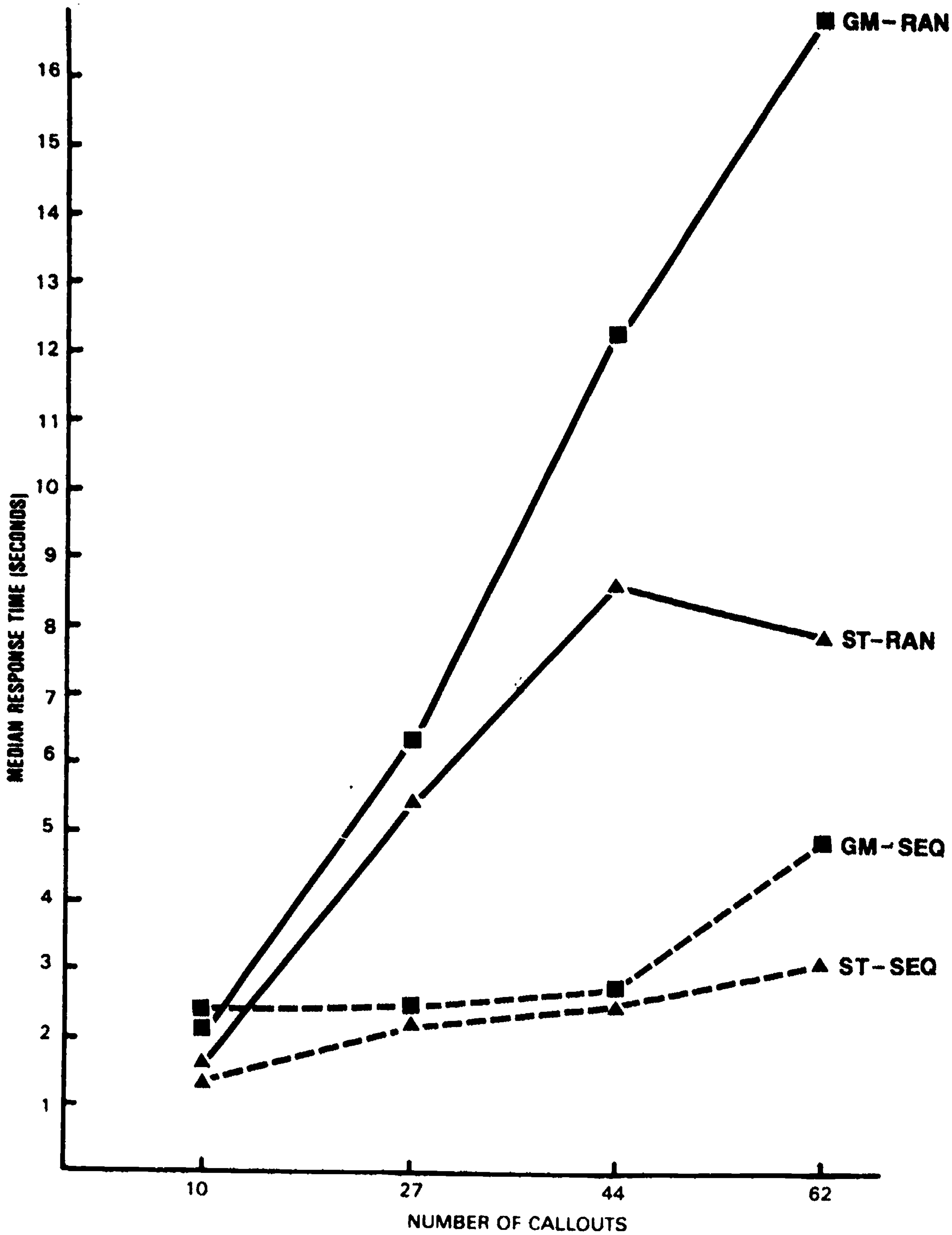

Figure 13. A comparison of Task 1 performance of ST and GM groups on exploded view, sequence and random conditions.

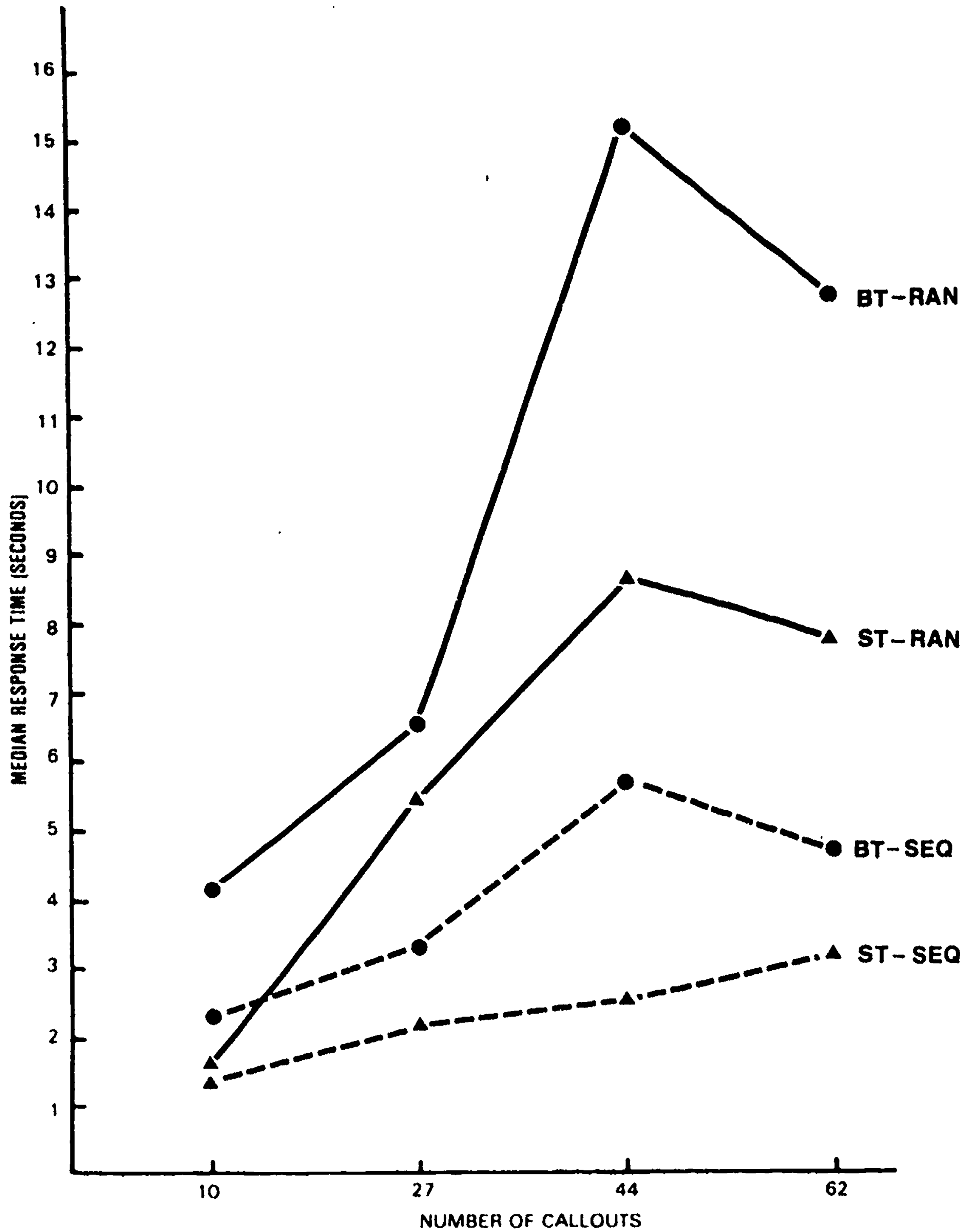

Figure 14. A comparison of Task 1 performance of ST and BT groups on exploded view, sequence and random conditions.

stimulus would have callouts in sequence apparently alerted the subject as to where his search should begin and how it should proceed. If this orientation response generalizes to actual job tasks, then the user's task would be greatly simplified by the knowledge that callouts would always be in sequence.

When callouts are in random order, on the other hand, there is a significant increase in the time required to locate information as the number of callouts increases. Note in Figures 13 and 14 that, for all groups, the time required in the 62-callout situation is three or more times that required when there are 10 callouts. Similarly, the time required for the 62-callout condition when the numbers are in random order is from two to four times as long as the analogous situation when the numbers are in sequence. Finally, both the GMs and BTs tend to take significantly longer than the STs when there are 62 callouts, and the BTs take significantly longer when there are 44 callouts as well. It is apparent again that the GMs and BTs experience more difficulty than STs when the number of callouts reaches 44, and considerably more difficulty for 62 callouts.

<u>Task 2 Findings</u>. Task 2 profiles comparing GMs and BTs with STs can be seen in Table 3 and in Figures 15 and 16, respectively. In Task 2 the subject must search for a part name in a table, determine the callout number for that part, and then locate that number on the drawing. As mentioned earlier, the time increment (based on a study of STs) required to search the table is subtracted out of total time before comparisons are made on this task. Figures 15 and 16 show only this corrected time. When callouts are in sequence, there is a much greater tendency toward an increase in the time required as the number of callouts increases. The time required (after the correction has been applied) is up to twice as long for 62 callouts as for 10 callouts. Since the corrected times for Task 2 should follow the same pattern as the actual times for Task 1 (i.e., no increase in time as the number of callouts increases), this systematic increase requires some explanation. The simplest hypothesis is that the table-search-time correction applied to these data is to some degree inappropriate. The linear function representing the correction was derived from data on STs. The function may in fact be [illegible]linear, and a different function may be required for the other rating [illegible]. More investigation is needed.

[illegible] differences between SEQ and RAN for 27, 44, and 62 callouts are [illegible] and sizable for each rating group. Furthermore, the differences between both GM and BT samples and the ST sample with 62 callouts amount to an average of 4 seconds for GMs and almost 5 seconds for BTs. The differences [illegible] callouts are less pronounced for the GMs but are even more extreme for [illegible]. This finding--that the mechanical ratings in general require more [illegible] locate information when as many as 62 callouts are present--is [illegible] and may have serious implications for the construction of drawings [illegible] these ratings.

<u>[illegible] Findings</u>. As in the Task 3 analysis of the cross-sectional view, [illegible] no consistent difference between sequential and random orders (see [illegible] would be expected. There is a slight effect that depends [illegible] on the drawing. There is a tendency among all

Table 3

Task 2, Exploded View, SEQ and RAN
Median Response Times: ST(Hi), ST(Lo), GM BT

Rating Group	Number of Callouts 10	27	44	62
Task 2 SEQ				
ST(Hi)	1.38	2.10	2.55	3.05
ST(Lo)	1.20	2.30	5.25	3.40
GM	2.27	2.38	2.75	4.85
BT	2.23	3.18	5.73	4.63
Task 2 RAN				
ST(Hi)	1.65	5.40	8.60	7.85
ST(Lo)	1.70	4.95	9.60	10.90
GM	2.05	6.25	12.15	16.85
BT	4.05	6.45	15.05	12.65

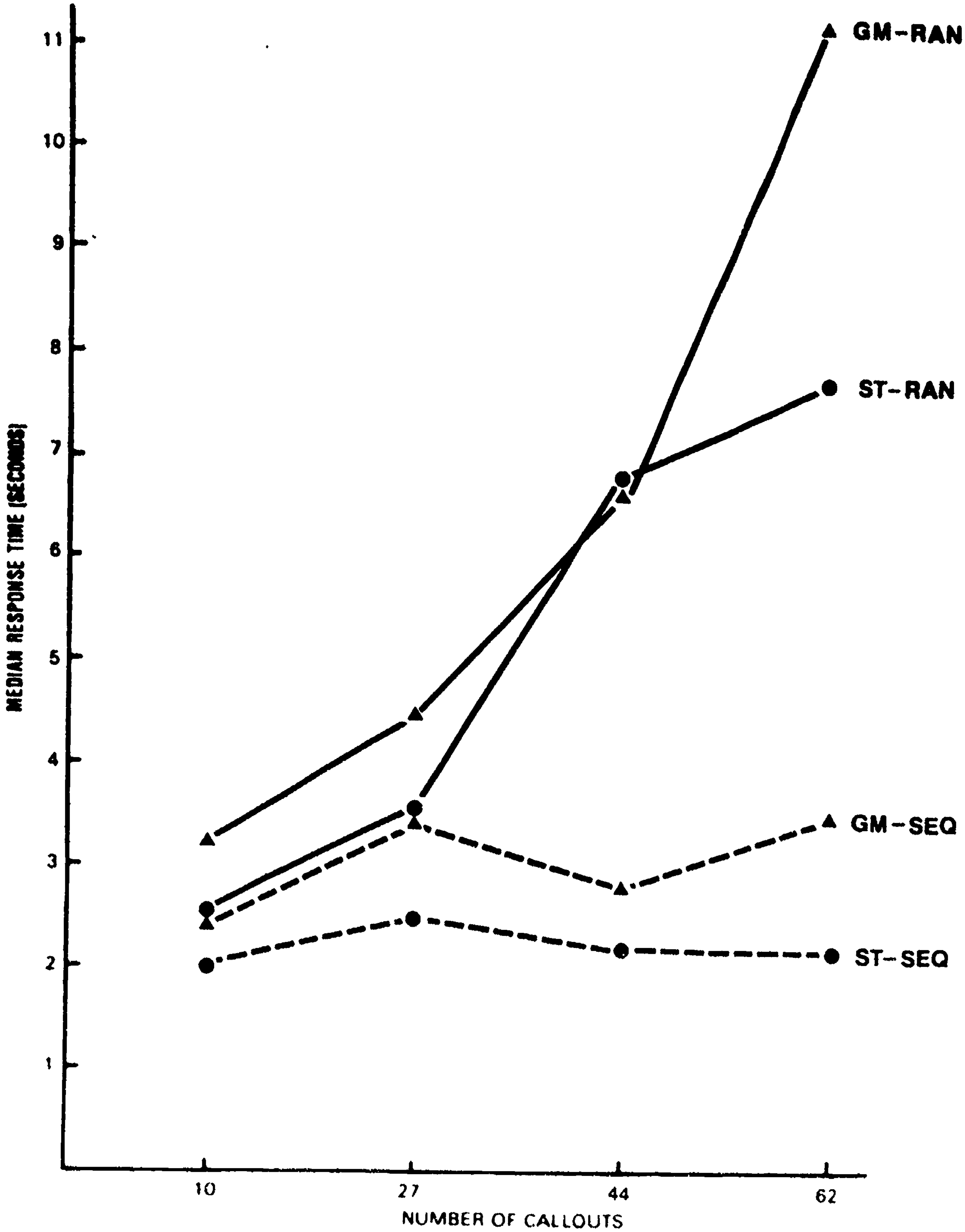

Figure 15. A comparison of Task 2 performance of ST and GM groups on exploded view, sequence and random conditions.

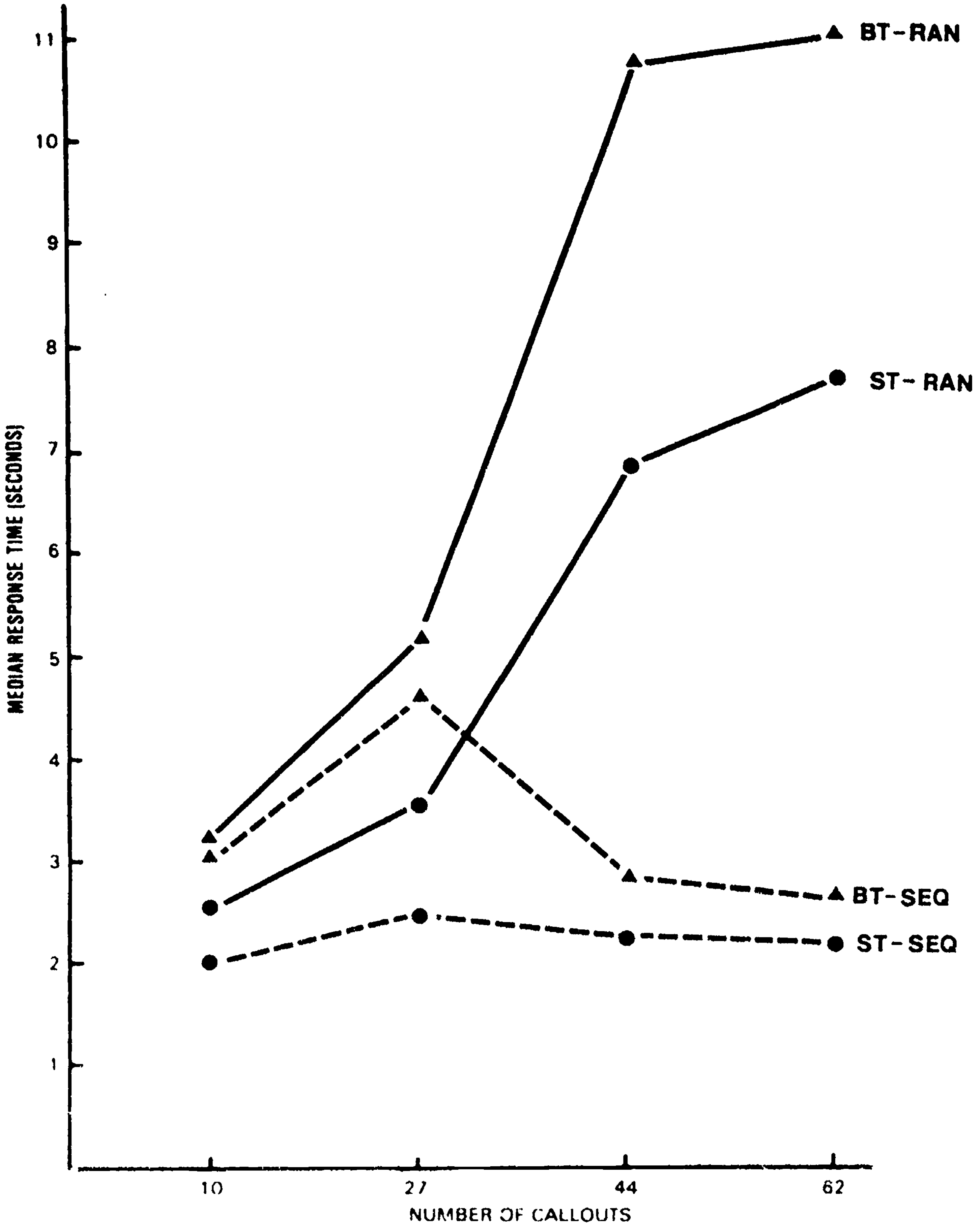

Figure 16. A comparison of Task 2 performance of ST and BT groups on exploded view, sequence and random conditions.

Table 4

Task 3, Exploded View, SEQ and RAN
Median Response Times: ST(Hi), ST(Lo), GM, BT

Rating Group	Number of Callouts 10	27	44	62
Task 3 SEQ				
ST (Hi)	2.80	3.20	3.20	4.00
ST (Lo)	3.38	3.53	3.50	4.08
GM	3.15	4.40	4.20	4.60
BT	3.50	3.55	4.10	5.00
Task 3 RAN				
ST (Hi)	2.40	3.05	3.35	3.35
ST (Lo)	2.83	3.40	3.65	4.13
GM	2.90	3.73	4.58	4.78
BT	3.25	4.00	4.15	4.50

subjects to take longer to determine the nomenclature of a part marked on the drawing as the number of callouts increases. It is hypothesized that this difference (which may be too small to be of concern) is due to two factors. First, as the number of callouts increases, there is a greater likelihood of misreading the number of the target item, due simply to clutter. Subjects were observed taking considerably more care with large numbers of callouts to ensure that they did not make mistakes. Second, there is certain to be some increase in the time required to locate a callout number deep in a table as opposed to near the top of the table. This is not as critical a function as searching for the name of a part in a table, for which the table-search correction was applied in Task 2. It merely involves locating a particular number in a column of numbers arranged in numerical order and reading the part name associated with that number. The time involved is probably quite small and is perhaps not of practical significance. At any rate, it is difficult to see how tables could be organized differently to make the process easier.

Circling Callouts and Extending Leaders

Circling number callouts and extending leaders to enhance visual scanning were expected to have much weaker effects than the sequence-random variable. In fact, it was anticipated that, if the numbers were in sequence, there would be no effect due to these "cosmetic" variations. If this were the case, then the C and E variables would prove beneficial only when the numbers were in random order and when there were many callouts to scan. To test this hypothesis, both the sequence and random conditions for 44 and 62 callouts, Tasks 1 and 2, were examined. The results were mixed and generally inconsistent.

Figure 17 shows the profiles of median response times for Task 1 with 44 callouts in random order. This is probably the only instance from which clearcut conclusions might have been drawn. With the exception of the dip in the profile for GMs for the circled/not extended (C/NE) condition, these results are what would have been predicted. This figure shows the extension variable to be the more powerful of the two, and circling to be superior to not circling. In the extended condition, callouts are placed, for the most part, in straight vertical and horizontal lines near the outer edges of the illustration (e.g., Figure D-2). Under these circumstances, one would presume that the search for a particular callout number, without the cues provided by having the callouts in sequence, would be enhanced by the ability to scan in straight lines across the top and bottom and up and down the sides of the drawing. The results in this particular instance (Figure 17) would seem to bear out that hypothesis: The best performance is attained when the leaders are extended and the numbers are circled, and the worst performance is attained when leaders are not extended and the numbers are not circled. The worst performance for each group (NC/NE) is two to three times as long as the best performance.

Figure 18 profiles the median response times for Task 1 with 62 callouts in sequence, and shows much of the inconsistency found in these results. Results for the T and BT samples indicate that, even with the callouts in sequence, some effect of the C/E variation is present. The conclusion drawn

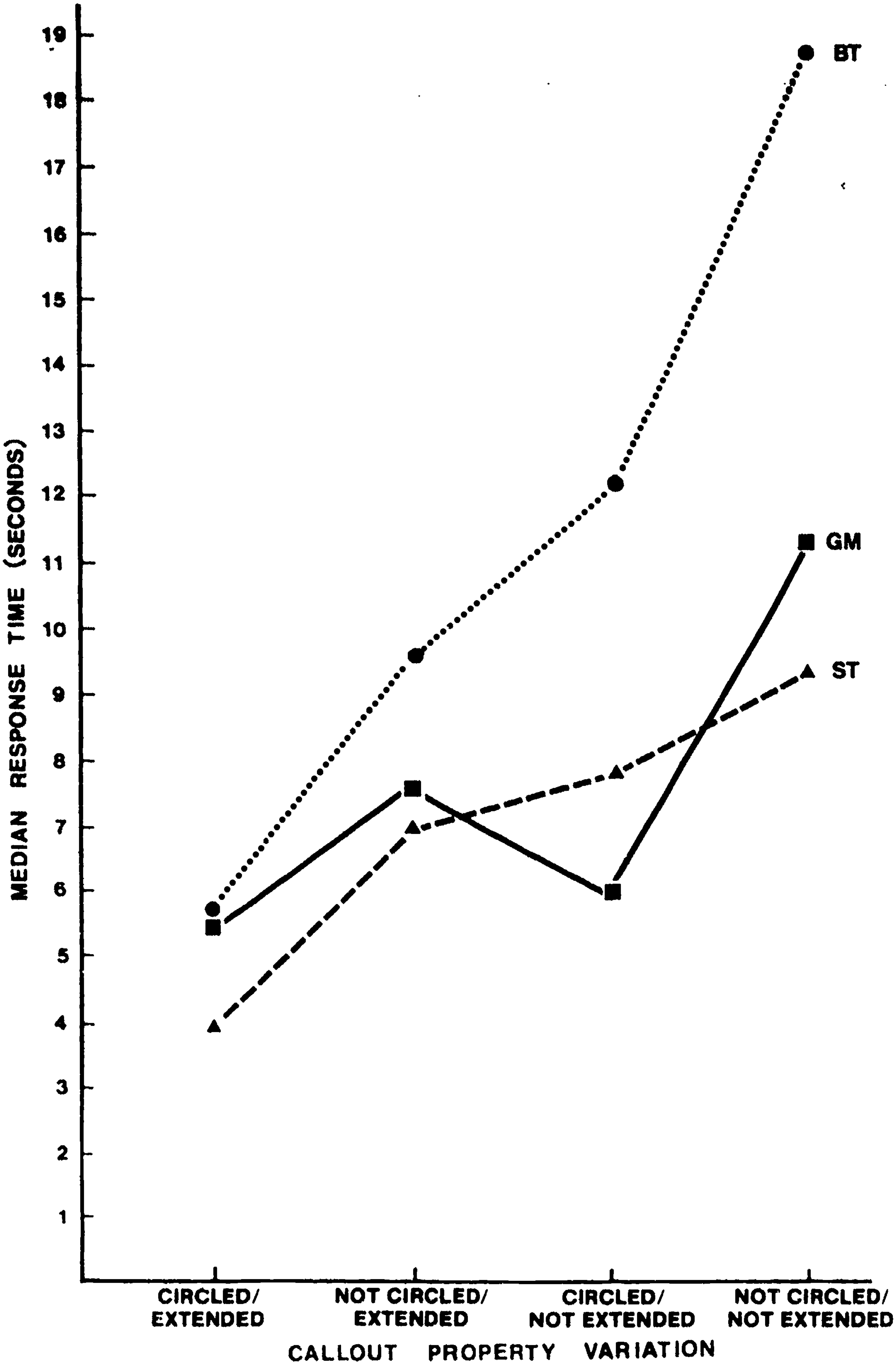

Figure 17. A comparison of ST, GM, and BT performance in the four circle-extend conditions, Task 1, 44 callouts in random order.

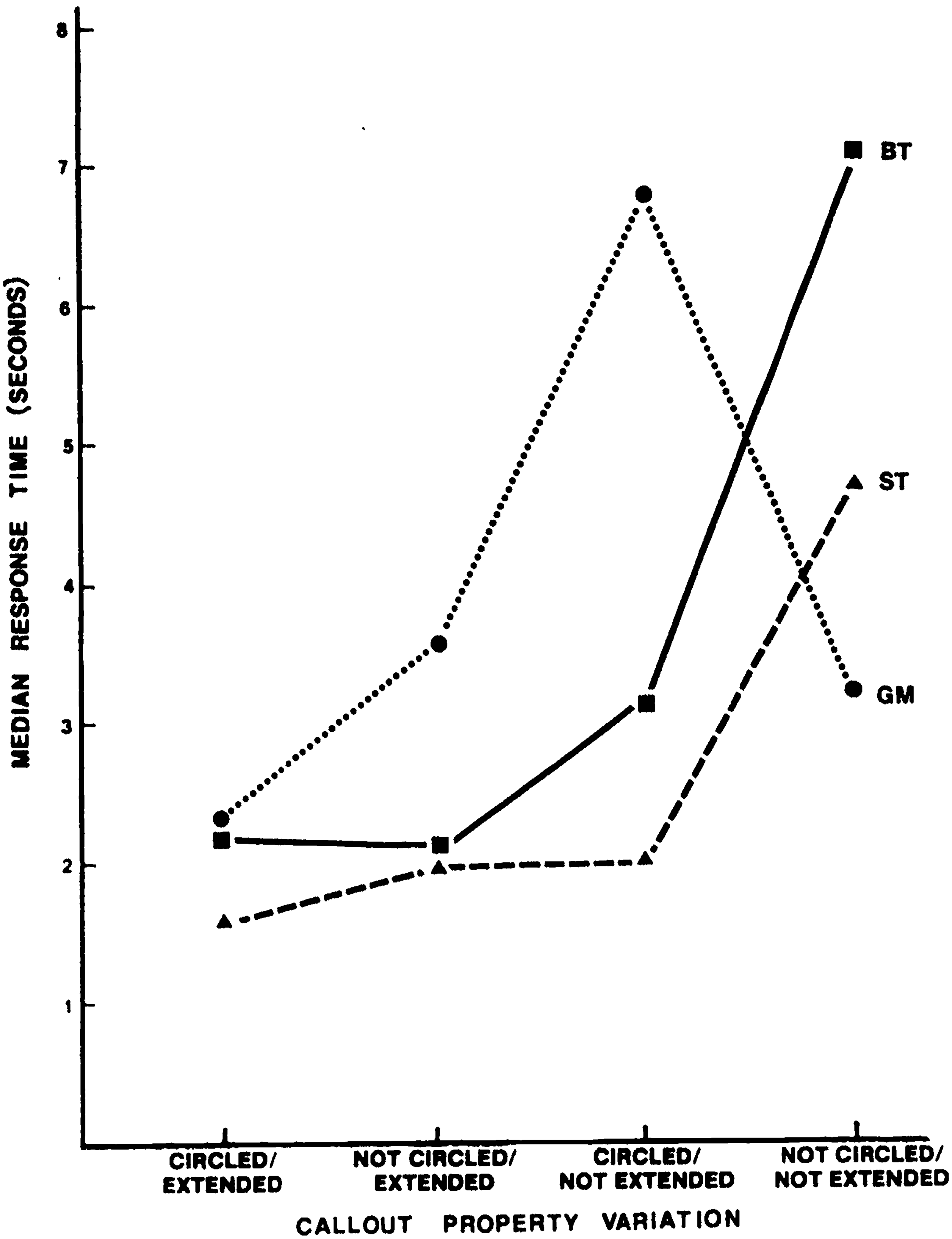

Figure 18. A comparison of ST, GM, and BT performance in the four circle-extend conditions, Task 1, 62 callouts in sequence.

from these profiles is that there is a negative effect on scanning efficiency if the callouts are neither circled nor extended. Again, the uncircled, embedded callout numbers in this condition would be expected to be masked by the features of the drawing itself. According to this figure, there is no detrimental effect caused by simply not extending the leaders; performance is degraded only when the nonextended leaders are also not circled. None of the effects indicated here for the sequence condition are as strong as those found for random ordering, as expected. The profile for the GM sample leads to entirely different conclusions than those of the STs and BTs. The differences noted cannot be reconciled using the available data.

A detailed examination of all of the results involving circling and extending might, if nothing else, lead to questions that should be investigated more completely. Figure 19 points to one possible area of interest. The profile for STs generally conforms to that in Figure 19, with 62 callouts in sequence; that is, it indicates little (if any) difference among the variations except for the tendency for the NC/NE stimulus to require a longer search time. Perhaps the most intriguing feature of Figure 19, however, is the similarily of the GM and BT profiles and the distinct difference between both of these and the STs. The circled/nonextended condition in this case involved a rather difficult task: locating callout number 11, which is deeply embedded in the outlines of the drawing itself. Interestingly, STs appeared to have very little difficulty in locating it, whereas both the GMs and BTs required about four times as long. These differences are highly significant, and raise the question of possible differences in abilities of the mechanical ratings compared to the electronics rating. Much more investigation is required to determine the nature of these differences and their implications for graphic design for the various ratings.

Although conclusions from the circle/extend conditions cannot be drawn with confidence, the overall data indicate that circling callout numbers and extending leaders are weak variables at best, even when the number of callouts is large, and especially if the callout numbers are in sequence. The results do, however, again suggest that user characteristics reflected in Navy rating should influence the selection of graphic presentation features.

Zones

The tasks performed by the subjects in this study did not lend themselves to the use of zones. The subjects frequently seemed confused on these test items and the results are not enlightening. Comparing the Task 4 and 5 items with their corresponding Task 1 and 2 items, the items with zones invariably had longer search times. Zones apparently are not useful for locating parts when a number callout must also be used for verification.

There were no significant differences among the Task 4 distributions. In Task 5, the C/E cell was significantly lower than the others, which would be reasonable except that the overall data on circling and extending leaders makes this finding suspect.

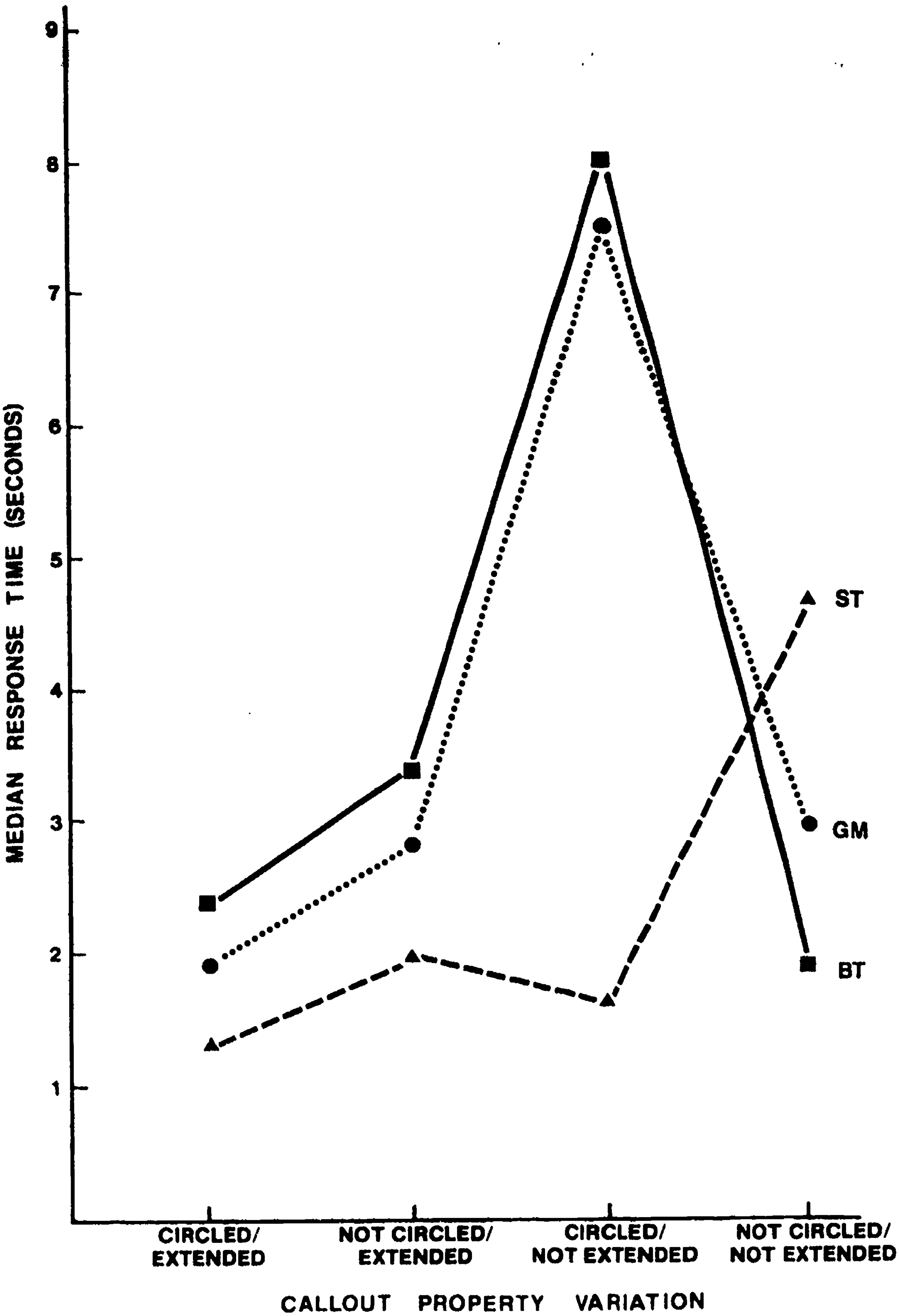

Figure 19. A comparison of ST, GM, and BT performance in the four circle-extend conditions, Task 1, 44 callouts in sequence.

Cross-sectional versus Exploded Views

The NUM-SEQ and NUM-RAN conditions of the cross-sectional drawing were similar to the exploded-view drawings in that they had no nomenclature. This allowed a comparison between responses to the two drawings. For each number-of-callouts step, a comparison was made between NUM-SEQ and the combined SEQ conditions for the exploded view, and between NUM-RAN and the combined RAN conditions for the exploded view. Of the 24 comparisons, 11 were not significant at the .05 level and 5 were significant at the .001 level. Of these five, four indicated somewhat longer times for the cross-sectional view. The conclusion is that responses to the two drawings were, for the most part, very similar; either type of drawing could be used in this type of study. Confusing elements in this particular cross-sectional drawing probably accounted for the significant differences.

Independence of Observations

Correlations might exist in the data because the same subjects were used for groups of test items. If speed of response is a subject trait, and one of the groups of subjects happened to have a large proportion of fast subjects, this would be reflected in conditions scattered throughout the experiment, causing significant differences, not because of stimulus characteristics, but because of spurious subject group characteristics. Correlated data could thus generate an excess of significant sample differences where no differences really exist.

If search speed is not a subject trait, but is instead associated only with test items, then the observations can be considered essentially independent for the purpose of performing other analyses. To assess the potential correlations in these data, three analyses were performed on the ST data using the Kendall coefficient of concordance method to calculate average Spearman rank difference correlations.

The first analysis may be thought of as pairing the 36 subjects in each group to yield all possible pairs, calculating the rank difference correlation (rho) across the 40 test items, and finding the average rho of the 630 pairs. The average correlations turned out as follows:

Group	Average Rho
A	.74
B	.70
C	.73
D	.71

These average correlations are significantly different from zero well beyond the .001 level.

The interpretation of such a substantial average correlation is that the subjects reacted to the items similarly; i.e., items with short times for one subject tended to have short times for the others. There were "hard" items and "easy" items; response time is definitely related to the test item. Additionally, the close agreement between groups is an indication that the groups were equivalent.

The second analysis was similar, except that the test items were taken pairwise, with the correlations calculated across subjects. In this case, a high average correlation would mean that subjects are individually consistent; that is, there are fast subjects and slow subjects. Low correlations would indicate that subject responses tended to be independent of the subject, with very little carryover from one test item to another.

Group	Average Rho
A	.16
B	.13
C	.17
D	.14

These correlations are also significant beyond the .001 level, but are uniformly low, indicating almost no relationship between test items.

Taken together, these results indicate that it is justifiable to regard all the scores as essentially independent measures reflecting stimulus characteristics.

A third analysis confirmed the second. Because of the way the items were assigned to groups, certain similar items were administered to the same subjects. Specifically, there were 10 pairs of Task 1 items of this type, in which the two items in the pair differed only in having either 27 or 62 callouts. The correlation was calculated for each of the 10 items, yielding rhos ranging from -.08 to .33. They are uniformly low, and the highest fails to meet the .05 level of significance, further indicating the independence of the observations.

Value of the Results

Three questions might be raised about this investigation:

1. Aren't the results intuitively obvious?

2. Will the results generalize to the work environment?

3. Even the longest search times are quite short; will these proposed guidelines really make much difference?

The major findings--that numbers are easier to find if they are in sequence, that tables should be organized alphabetically or numerically depending on the user's entry information, and that drawings should be tailored to different uses--seem rational and obvious. The importance of this study is twofold: It provides the beginnings of an objective, numerical measure of the cost of violating these rational principles; and it demonstrates that the guidance and requirements found in current military procurement documents often do not conform to the results of this study.

With regard to the generalizability of the findings, it should be noted that the subjects' task in the experiment was not truly a job task simulation, but rather a small part of an actual job task. However, the search times obtained in the study are probably underestimates of on-the-job times, since the subjects were highly motivated to "beat the clock" in spite of instructions to relax and pace themselves normally. Ordinary distractions and discomforts of the work environment were absent, and subjects' whole attention was on the task itself. It is probable that, in the work environment, the same relative magnitudes or ratios would appear, but the actual search times would be longer.

Finally, even though the time for each information search is short, these are small tasks that occur with great frequency, so the total time could be appreciable. There is also an annoyance factor that was observed but not measured or recorded during the data collection; that is, subjects who had trouble finding a number or nomenclature sometimes became quite agitated. On the job, if the use of a drawing appears to make the job longer instead of shorter, or harder instead of easier, then the technician may reject the drawings or the entire manual whenever possible. Every effort should be made to make the data in technical manuals as accessible and helpful to the user as possible.

Evaluation of the Study

The purpose of this study was not only to generate data on which to base guidelines, but also to evaluate the feasibility of attempting an objective assessment of graphic comprehension or usefulness. As a prototype for future investigations, the study's approach appears to have excellent possibilities for solidifying comprehension requirements in technical manual procurement documents. The approach is different from other work in this area, because it focuses directly on the behavior of the technician as he attempts to extract needed data from a drawing. It does not attempt a theoretical formulation of graphic comprehension, nor does it attempt to operationally define stimulus features such as "density" and "clutter." It asks what the technician is doing with the drawing, and what factors might influence that activity. This method has the virtue of generating empirical relationships that should have direct application and, it is hoped, will provide a basis for theoretical developments regarding perception and human information processing in complex environments.

The most serious shortcoming in this study was its failure to control adequately for the two sources of extraneous variation: The location of the targets on the drawings and the position of the information in the accompanying tables. The impact of target location, both on the illustration and in the table, was greatly underestimated. It is hypothesized that systematic perceptual variations caused some target items to take much longer to locate than others (notably in the random conditions) and confounded certain results. Table search time, of course, is part of the total performance time, but based on data dealing only with table search time, this effect can be dealt with mathematically.

Overall, the practical impact of these deficiencies is limited. The sequence-random effect was very strong, and leads to the conclusion that callouts should be arranged in sequence at all times. The hypothesized perceptual phenomenon is a problem only in the random conditions, which the results of this study suggest should never be used. It poses, at this time, an interesting theoretical question but not a practical one.

CONCLUSIONS AND RECOMMENDATIONS

1. For part location by callout number, callouts should always be arranged in numerical sequence on the drawing, even when the number of callouts is very small. When callout numbers are given in procedural steps, they should be in sequence on the drawing rather than in the text. If the numbers are in sequence, then the number of callouts may be quite large, certainly greater than the 62 callouts used in this study.

2. For part location by nomenclature, nomenclature callouts may be used if the number of callouts is 10 or less. Otherwise, an alphabetical table should be provided to key the nomenclatures to number callouts, which should be in sequence on the drawing.

3. For part identification (finding the nomenclature when the location is known), nomenclature callouts are superior to numbers keyed to a table even when the number of callouts is so large that the drawing appears excessively cluttered.

4. If the numbers are in sequence, then devices to enhance the discrimination and visual scanning of number callouts, such as circling and aligning the numbers, are probably unnecessary.

5. Zones are not useful for locating parts when a number callout must also be used for verification.

6. Since the guidelines differ with the type of information search, drawings must be designed for specific information-search tasks.

7. There appears to be a consistent difference between the combined GM/BT sample and the ST sample with regard to overall information-search performance. Since this occurs also in tasks not involving reading, more general perceptual or behavioral factors are responsible. These need to be identified and investigated.

8. Although isolating the technical manual user's information-search behaviors and varying the features of drawings that influence search speed and accuracy appear very promising, care must be taken in future studies to randomize, counterbalance, or measure the effect of target location in the stimulus materials. Inadequate control of this variable in the present study caused confounding in certain desired comparisons, but need not cause problems in future studies.

9. Clarification of the graphic comprehension issue should be pursued through empirical studies of users' information-search behavior and the [illegible] variations that influence its efficiency.

APPENDIX C

TEST-ITEM DISTRIBUTION STATISTICS

For each table a Kruskal-Wallis k-sample test of distribution differences was performed, yielding H, which is distributed as Chi-square with k-1 degrees of freedom. The result is indicated under each table. Tables for Tasks 2 and 5 show values corrected for table-search time.

Table C-1

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
CROSS-SECTIONAL VIEW: NUM-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.30	0.30	0.70	0.90
Q1	1.15	1.00	1.25	1.70
Q2 (Median)	1.55	1.30	1.80	2.35
Q3	2.00	2.20	2.60	3.05
HI Score	3.60	3.20	3.60	6.50
HI-LO	3.30	2.90	2.90	5.60
Q3-Q1	0.85	1.20	1.35	1.35
N	36	36	36	36
Group	A	D	C	D

Note. $H = 19.98$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	1.10	2.10	1.30
Q1	1.15	1.30	2.90	2.65
Q2 (Median)	1.80	2.90	3.20	3.60
Q3	2.05	3.20	4.25	6.45
HI Score	3.50	5.30	8.20	15.90
HI-LO	2.50	4.20	6.10	14.60
Q3-Q1	0.90	1.90	1.35	3.80
N	15	15	15	15
Group	A	D	C	D

Note. $H = 21.22$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-2

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
CROSS-SECTIONAL VIEW: NUM-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.90	1.10	1.20
Q1	1.25	3.20	4.95	4.00
Q2 (Median)	2.00	3.80	7.75	6.50
Q3	2.70	4.80	15.60	9.00
HI Score	5.00	14.50	40.20	18.30
HI-LO	4.50	13.60	39.10	17.10
Q3-Q1	1.45	1.60	10.65	5.00
N	36	36	36	36
Group	B	A	D	A

Note. $H = 69.26$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	1.60	1.60	2.40
Q1	1.80	3.80	4.90	4.60
Q2 (Median)	2.15	5.00	15.90	7.10
Q3	3.00	8.10	23.45	13.30
HI Score	6.20	11.90	63.00	20.90
HI-LO	5.10	10.30	61.40	18.50
Q3-Q1	1.20	4.30	18.55	8.70
N	16	15	15	15
Group	[illegible]	A	[illegible]	A

Note. H = [illegible]

Table C-3

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
CROSS-SECTIONAL VIEW: N/N-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.70	1.10	0.60
Q1	1.20	1.65	2.35	2.00
Q2 (Median)	1.85	2.80	3.00	2.40
Q3	2.40	3.20	3.70	3.55
HI Score	5.60	5.40	9.20	9.30
HI-LO	4.60	4.70	8.10	8.70
Q3-Q1	1.20	1.55	1.35	1.55
N	36	36	36	36
Group	C	B	A	B

Note. H = 20.14, p < .001 (p = .001 for H > 16.27)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	1.90	1.80	1.90
Q1	2.05	2.80	2.55	3.00
Q2 (Median)	2.20	3.15	3.20	3.50
Q3	3.25	4.00	4.05	4.10
HI Score	4.00	7.00	5.30	8.30
HI-LO	2.90	5.10	3.50	6.40
Q3-Q1	1.20	1.20	1.50	1.10
N	[illegible]	[illegible]	15	14
Group	C	B	A	B

Note. H = [illegible] (p = [illegible] for H [illegible] 7.82)

Table C-4

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
CROSS-SECTIONAL VIEW: N/N-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.60	0.60	1.20
Q1	1.20	1.20	3.95	4.55
Q2 (Median)	2.00	2.10	6.00	8.25
Q3	2.80	3.55	8.65	10.95
HI Score	6.40	7.30	31.40	17.00
HI-LO	5.90	6.70	30.80	15.80
Q3-Q1	1.60	2.35	4.70	6.40
N	36	36	36	36
Group	D	C	B	C

Note. $H = 65.72$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	1.30	1.60	3.60
Q1	1.40	1.95	4.80	7.70
Q2 (Median)	2.00	2.90	7.95	10.60
Q3	2.70	6.25	14.30	13.55
HI Score	4.10	7.60	20.90	25.20
HI-LO	3.10	6.30	19.30	21.60
Q3-Q1	1.30	4.30	9.50	5.85
N	15	15	14	15
Group	D	C	B	C

Note. $H = 32.63$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-5

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: SEQ/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	1.10	0.40	0.80
Q1	1.80	1.65	1.10	1.40
Q2 (Median)	2.00	2.30	1.25	2.00
Q3	2.65	3.10	1.65	2.75
HI Score	5.00	6.20	4.50	5.60
HI-LO	3.90	5.10	4.10	4.80
Q3-Q1	0.85	1.45	0.55	1.35
N	36	36	36	36
Group	A	D	C	D

Note. H = 31.1, p < .001 (p = .001 for H > 16.27)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	2.20	1.10	1.90
Q1	1.90	3.20	1.50	2.60
Q2 (Median)	2.90	4.10	2.00	4.00
Q3	3.90	6.55	3.55	6.95
HI Score	10.90	20.60	5.10	12.00
HI-LO	9.60	18.40	4.00	10.10
Q3-Q1	2.00	3.35	2.05	4.35
N	15	15	15	15
Group	A	D	C	D

Note. H = 1[illegible].91, p < .01 (p = .01 for H > 11.34)

Table C-6

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: SEQ/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.40	0.50
Q1	1.00	1.20	2.00	1.15
Q2 (Median)	1.20	1.90	3.85	1.60
Q3	2.00	3.00	5.70	2.35
HI Score	5.00	9.00	15.00	4.80
HI-LO	4.50	8.50	14.60	4.30
Q3-Q1	1.00	1.80	3.70	1.20
N	36	36	36	36
Group	B	A	D	C

Note. H = 32.2, p < .001 (p = .001 for H > 16.27)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	1.10	1.20	1.00
Q1	1.30	1.30	5.35	1.15
Q2 (Median)	1.60	3.20	8.00	2.20
Q3	2.10	9.05	10.45	5.15
HI Score	3.20	15.80	28.00	11.80
HI-LO	2.20	14.70	26.80	10.80
Q3-Q1	0.80	7.75	5.10	4.00
N	14	15	15	15
Group	B	A	D	C

Note. H = 17.92, p < .001 (p = .001 for H > 16.27)

Table C-7

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: SEQ/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.60	1.20	0.70
Q1	1.80	2.30	2.25	1.20
Q2 (Median)	2.45	3.00	2.80	1.95
Q3	3.10	4.10	3.25	3.50
HI Score	6.90	8.60	5.80	8.00
HI-LO	6.00	7.00	4.60	7.30
Q3-Q1	1.30	1.80	1.00	2.30
N	36	36	36	36
Group	C	B	A	B

Note. $H = 12.87$, $p < .01$ ($p = .01$ for $H > 11.34$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.90	1.60	1.30
Q1	2.15	2.50	2.75	1.90
Q2 (Median)	2.60	3.95	3.10	3.10
Q3	5.55	5.10	4.90	4.60
HI Score	12.10	9.80	11.20	9.00
HI-LO	10.80	7.90	9.60	7.70
Q3-Q1	3.40	2.60	2.15	2.70
N	15	14	15	14
Group	C	B	A	B

Note. $H = 1.75$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-8

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: SEQ/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.60	1.00	0.90	0.50
Q1	1.30	2.00	1.20	2.60
Q2 (Median)	2.20	2.95	1.85	4.65
Q3	3.85	5.20	2.90	7.05
HI Score	9.00	26.20	7.10	12.50
HI-LO	8.40	25.20	6.20	12.00
Q3-Q1	2.55	3.20	1.70	4.45
N	36	36	36	36
Group	D	C	B	A

Note. $H = 22.96$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.30	0.80	2.20
Q1	2.60	3.55	1.90	3.00
Q2 (Median)	3.80	5.10	2.50	5.00
Q3	8.65	7.00	5.00	7.60
HI Score	17.70	32.90	7.20	18.00
HI-LO	16.40	31.60	6.40	15.80
Q3-Q1	6.05	3.45	3.10	4.60
N	15	15	14	15
Group	D	C	B	A

Note. $H = 7.77$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-9

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: RAN/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	0.80	2.30	1.70
Q1	2.00	2.05	2.95	4.65
Q2 (Median)	2.20	3.40	3.95	8.55
Q3	2.95	6.25	5.05	16.10
HI Score	7.50	15.80	13.80	24.20
HI-LO	6.60	15.00	11.50	22.50
Q3-Q1	0.95	4.20	2.10	11.45
N	36	36	36	36
Group	D	C	B	C

Note. $H = 48.43$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.70	2.10	5.00
Q1	2.45	4.00	3.80	7.35
Q2 (Median)	3.00	5.10	5.55	13.90
Q3	4.05	15.70	7.50	35.80
HI Score	6.80	32.00	19.80	60.80
HI-LO	5.50	30.30	17.70	55.80
Q3-Q1	1.60	11.70	3.70	28.45
N	15	15	14	15
Group	D	C	B	C

Note. $H = 25.72$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-10

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: RAN/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.00	2.40	0.60
Q1	1.80	2.35	5.50	6.25
Q2 (Median)	2.55	3.30	7.85	9.85
Q3	3.35	5.00	13.35	18.15
HI Score	6.00	7.60	51.20	52.20
HI-LO	5.10	6.60	48.80	51.60
Q3-Q1	1.55	2.65	7.85	11.90
N	36	36	36	36
Group	C	B	A	B

Note. $H = 74.36$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	2.10	1.40	1.30
Q1	2.80	3.70	5.55	8.10
Q2 (Median)	3.20	4.05	8.10	10.85
Q3	5.55	5.10	17.05	15.30
HI Score	8.00	9.10	50.10	43.80
HI-LO	6.30	7.00	48.70	42.50
Q3-Q1	2.75	1.40	11.50	7.20
N	15	14	15	14
Group	C	B	A	B

Note. $H = 20.82$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-11

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: RAN/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.50	2.00	2.10
Q1	2.90	2.20	4.10	4.70
Q2 (Median)	4.15	3.20	6.95	6.40
Q3	5.55	4.60	12.95	10.95
HI Score	23.60	11.10	26.50	35.20
HI-LO	22.30	9.60	24.50	33.10
Q3-Q1	2.65	2.40	8.85	6.25
N	36	36	36	36
Group	B	A	D	A

Note. $H = 31.16$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.90	1.20	4.00	2.00
Q1	2.80	2.80	6.65	6.20
Q2 (Median)	3.55	3.70	7.90	11.60
Q3	5.90	7.50	14.70	22.20
HI Score	34.20	11.40	16.50	36.90
HI-LO	32.30	10.20	12.50	34.90
Q3-Q1	3.10	4.70	8.05	16.00
N	14	15	15	15
Group	B	A	D	A

Note. $H = 16.42$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-12

Test Item Distribution Statistics
Task 1 (Point to Part Given Callout Number)
EXPLODED VIEW: RAN/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.60	0.80	1.40	1.60
Q1	1.25	2.55	4.80	3.00
Q2 (Median)	1.85	4.85	9.20	6.00
Q3	2.80	8.35	11.20	10.70
HI Score	5.00	46.00	28.30	21.20
HI-LO	4.40	45.20	26.90	19.60
Q3-Q1	1.55	5.80	6.40	7.70
N	36	36	36	36
Group	A	D	C	D

Note. $H = 52.18$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	2.10	5.00	2.30
Q1	2.05	3.35	8.60	4.90
Q2 (Median)	3.00	6.10	11.50	12.30
Q3	4.90	21.45	22.20	17.95
HI Score	11.00	36.50	37.10	51.90
HI-LO	9.90	34.40	32.10	49.60
Q3-Q1	2.85	18.10	13.60	13.05
N	15	15	15	15
Group	A	D	C	D

Note. $H = 20.61$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-13

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: NOMEN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.40	1.60	1.20
Q1	1.10	3.90	2.95	4.75
Q2 (Median)	1.55	6.20	5.80	8.50
Q3	2.45	8.90	11.05	14.75
HI Score	6.50	19.50	36.30	40.30
HI-LO	5.60	18.10	34.70	39.10
Q3-Q1	1.35	5.00	8.10	10.00
N	36	36	36	36
Group	D	A	B	C

Note. H = 59.93, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
[illegible]	2.00	2.10	1.80	2.00
[illegible]	2.05	4.85	4.00	3.80
Q2 (Median)	2.30	9.90	6.95	6.10
Q3	4.20	12.60	8.60	17.25
HI Score	8.60	18.10	27.20	28.10
[illegible]	6.60	16.00	25.40	26.10
[illegible]	2.15	7.75	4.60	13.45
[illegible]	[illegible]	15	14	15
[illegible]	[illegible]	A	B	[illegible]

[illegible]

Table C-14

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
CROSS-SECTIONAL VIEW: NUM-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.60
Q1	0.90	2.10	0.55	2.70
Q2 (Median)	2.05	3.40	2.85	4.70
Q3	2.40	6.65	4.35	7.05
HI Score	8.60	19.50	15.10	23.90
HI-LO	8.10	19.00	14.60	23.30
Q3-Q1	1.50	4.55	3.80	4.35
N	36	36	36	36
Group	B	C	D	A

Note. $H = 27.52$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.20	0.50	0.50	2.90
Q1	1.50	3.90	1.50	3.90
Q2 (Median)	2.25	5.30	3.00	6.00
Q3	2.90	8.25	8.50	15.55
HI Score	5.00	10.80	13.30	23.20
HI-LO	3.80	10.30	12.80	20.30
Q3-Q1	1.40	4.35	7.00	11.65
N	14	15	15	15
Group	B	C	D	A

Note. H = [illegible], p [illegible] .001 (p = .001 for H [illegible] 16.27)

Table C-15

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: NUM-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.90
Q1	0.80	2.15	5.80	7.70
Q2 (Median)	1.60	4.40	9.25	11.60
Q3	2.10	6.75	13.05	13.20
HI Score	5.30	19.30	25.60	36.20
HI-LO	4.80	18.80	25.10	35.30
Q3-Q1	1.30	4.60	7.25	5.50
N	36	36	36	36
Group	C	D	A	B

Note. $H = 70.71$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	0.50	0.70	2.70
Q1	1.45	2.15	3.25	8.10
Q2 (Median)	2.80	5.70	9.60	11.60
Q3	4.20	9.60	12.90	18.10
HI Score	4.90	20.10	21.50	24.70
HI-LO	3.80	19.60	20.80	22.00
Q3-Q1	2.75	7.45	9.65	10.00
N	15	[illegible]	15	14
Group	[illegible]	D	A	B

Note. [illegible]

Table C-16

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
CROSS-SECTIONAL VIEW: N/N-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	2.30	1.30	1.80
Q1	1.30	5.90	6.00	7.00
Q2 (Median)	2.30	8.05	10.25	13.25
Q3	3.00	11.90	15.15	17.05
HI Score	4.10	104.00	38.00	46.00
HI-LO	3.60	101.70	36.70	44.20
Q3-Q1	1.70	6.00	9.15	10.05
N	36	36	36	36
Group	D	A	B	C

Note. H = 70.92, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.50	1.00	5.70	2.20
Q1	2.20	7.30	6.70	9.25
Q2 (Median)	3.00	13.10	9.15	15.40
Q3	3.90	24.40	14.00	30.45
HI Score	4.80	46.00	21.90	66.80
HI-LO	3.30	45.00	16.20	64.60
Q3-Q1	1.70	17.10	7.30	21.20
N	15	15	14	15
Group	D	A	B	C

Note. H = [illegible], p [illegible] ($p = .001$ for $H > 16.27$)

Table C-17

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
CROSS-SECTIONAL VIEW: N/N-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.90	1.50	2.50
Q1	1.45	3.25	3.50	6.85
Q2 (Median)	2.05	4.70	5.45	11.75
Q3	3.00	7.65	8.55	26.95
HI Score	4.20	14.30	21.00	63.10
HI-LO	3.20	13.40	19.50	60.60
Q3-Q1	1.55	4.40	5.05	20.10
N	36	36	36	36
Group	A	B	C	D

Note. $H = 78.19$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.20	1.70	2.30	1.90
Q1	2.10	3.60	4.90	17.25
Q2 (Median)	2.70	6.95	10.10	31.00
Q3	3.40	7.80	17.45	50.25
HI Score	5.50	16.10	27.10	149.00
HI-LO	4.30	14.40	24.80	147.10
Q3-Q1	1.30	4.20	12.55	33.00
N	15	14	15	15
Group	A	B	C	D

Note. $H =$ [illegible], $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-18

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: SEQ/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	0.55	0.80	1.00	1.40
Q2 (Median)	1.40	1.60	2.10	3.10
Q3	1.90	2.70	4.25	5.75
HI Score	5.70	9.90	15.30	50.50
HI-LO	5.20	9.40	14.80	50.00
Q3-Q1	1.35	1.90	3.25	4.35
N	36	36	36	36
Group	B	A	D	C

Note. $H = 17.3$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	0.70	0.90	1.80	2.25
Q2 (Median)	1.10	2.00	2.90	4.50
Q3	2.00	8.80	8.05	13.20
HI Score	6.70	13.90	39.60	49.40
HI-LO	6.20	13.40	39.10	48.90
Q3-Q1	1.30	7.90	6.25	10.95
N	14	15	15	15
Group	B	A	D	C

Note. H = [illegible], p [illegible] .05 ($p = .05$ for $H > 7.82$)

Table C-19

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	0.50	0.50	1.10	0.50
Q2 (Median)	1.15	2.60	3.00	4.05
Q3	2.00	4.45	5.85	6.40
HI Score	3.00	27.50	14.40	41.10
HI-LO	2.50	27.00	13.90	40.60
Q3-Q1	1.50	3.95	4.75	5.90
N	36	36	36	36
Group	C	B	A	D

Note. $H = 15.03$, $p < .01$ ($p = .01$ for $H > 11.34$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	1.50	0.50	2.00	0.70
Q2 (Median)	2.10	2.00	4.20	1.80
Q3	2.95	3.60	7.25	11.95
HI Score	4.10	5.70	10.30	19.10
HI-LO	3.60	5.20	9.80	18.60
Q3-Q1	1.45	3.10	5.25	11.25
N	15	14	15	15
Group	C	B	A	D

Note. H = [illegible], $p < .05$ ($p = .05$ for $H > 7.82$)

Table C-20

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: SEQ/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	1.00	0.50
Q1	0.75	0.90	2.85	0.95
Q2 (Median)	1.35	2.80	8.20	3.10
Q3	2.65	5.00	12.60	5.85
HI Score	5.70	14.40	20.40	19.40
HI-LO	5.20	13.90	19.40	18.90
Q3-Q1	1.90	4.10	9.75	4.90
N	36	36	36	36
Group	D	C	B	A

Note. $H = 29.9$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	0.50	0.60	0.50
Q1	1.75	2.90	1.60	3.10
Q2 (Median)	2.70	3.40	2.45	4.00
Q3	5.95	4.30	9.60	4.60
HI Score	12.90	11.40	12.30	13.20
HI-LO	11.60	10.90	11.70	12.70
Q3-Q1	4.20	1.40	8.00	1.50
N	15	15	14	15
Group	D	C	B	A

Note. $H = .96$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-21

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	1.20	0.50	1.10	0.50
Q2 (Median)	2.20	0.95	1.70	1.25
Q3	3.50	5.45	2.90	8.60
HI Score	18.10	18.10	16.20	22.90
HI-LO	17.60	17.60	15.70	22.40
Q3-Q1	2.30	4.95	1.80	8.10
N	36	36	36	36
Group	A	D	C	B

Note. $H = 1.95$, $p > .05$ ($p = .05$ for $H > 7.82$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	2.10	0.50
Q1	1.00	0.50	3.20	5.00
Q2 (Median)	2.40	2.20	4.20	7.35
Q3	4.35	7.70	5.55	17.30
HI Score	10.40	15.30	9.30	22.60
HI-LO	9.90	14.80	7.20	22.10
Q3-Q1	3.35	7.20	2.35	12.30
N	15	15	15	14
Group	A	D	C	B

Note. $H = 10.96$, $p < .05$ ($p = .05$ for $H > 7.82$)

Table C-22

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: RAN/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	1.10	3.55	4.40	0.85
Q2 (Median)	2.00	6.20	8.60	3.70
Q3	2.75	8.35	16.10	8.85
HI Score	5.50	18.60	28.90	23.10
HI-LO	5.00	18.10	28.40	22.60
Q3-Q1	1.65	4.80	11.70	8.00
N	36	36	36	36
Group	A	D	C	B

Note. $H = 42.69$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	5.10	0.50
Q1	1.10	4.95	9.20	1.80
Q2 (Median)	2.30	7.70	15.00	7.75
Q3	3.70	16.75	27.00	9.80
HI Score	6.70	55.60	55.50	14.60
HI-LO	6.20	55.10	50.40	14.10
Q3-Q1	2.60	11.80	17.80	8.00
N	15	15	15	14
Group	A	D	C	B

Note. $H = 24.$[illegible], $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-23

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: RAN/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	0.50	3.30	1.50	0.50
Q2 (Median)	1.30	4.75	7.85	1.30
Q3	2.45	6.45	14.00	4.30
HI Score	7.40	29.50	54.30	19.00
HI-LO	6.90	29.00	53.80	18.50
Q3-Q1	1.95	3.15	12.50	3.80
N	36	36	36	36
Group	D	C	B	A

Note. $H = 31.44$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	1.20	3.30	1.10	2.50
Q2 (Median)	4.40	5.20	6.00	10.60
Q3	5.35	6.40	16.40	14.05
HI Score	21.20	21.90	33.90	18.80
HI-LO	20.70	21.40	33.40	18.30
Q3-Q1	4.15	3.10	15.30	11.55
N	15	15	14	15
Group	D	C	B	A

Note. $H = 2.08$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-24

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: RAN/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.80	0.50	0.50	0.50
Q1	3.20	2.40	9.05	7.70
Q2 (Median)	4.10	6.05	18.30	11.45
Q3	5.80	9.05	25.60	23.70
HI Score	27.20	40.60	73.90	56.30
HI-LO	25.40	40.10	73.40	55.80
Q3-Q1	2.60	6.65	16.55	16.00
N	36	36	36	36
Group	C	B	A	D

Note. $H = 42.4$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.80	1.40	2.70	2.40
Q1	4.45	2.90	10.00	17.05
Q2 (Median)	6.50	5.30	17.10	27.80
Q3	16.00	9.50	36.75	56.10
HI Score	21.10	15.30	51.60	70.50
HI-LO	18.30	13.90	48.90	68.10
Q3-Q1	11.55	6.60	26.75	39.05
N	15	14	15	15
Group	C	B	A	D

Note. $H = 23.55$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-25

Test Item Distribution Statistics
Task 2 (Point to Part Given Nomenclature)
EXPLODED VIEW: RAN/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.50	0.50
Q1	0.50	0.95	5.55	5.25
Q2 (Median)	1.20	2.90	8.80	13.90
Q3	2.60	5.95	13.50	27.65
HI Score	6.70	9.90	28.10	53.80
HI-LO	6.20	9.40	27.60	53.30
Q3-Q1	2.10	5.00	7.95	22.40
N	36	36	36	36
Group	B	A	D	C

Note. $H = 60.91$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.60	3.20	4.20
Q1	0.80	1.85	7.95	11.60
Q2 (Median)	1.15	7.70	9.60	14.30
Q3	2.00	14.95	24.60	39.15
HI Score	6.00	20.60	72.00	106.30
HI-LO	5.50	20.00	68.80	102.10
Q3-Q1	1.20	13.10	16.65	27.55
N	14	15	15	15
Group	B	A	D	C

Note. $H = 30.51$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-26

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
CROSS-SECTIONAL VIEW: NOMEN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.80	0.80	1.00
Q1	0.80	1.20	2.00	1.70
Q2 (Median)	1.20	1.30	2.25	2.00
Q3	1.50	1.95	3.00	2.60
HI Score	2.20	3.60	8.10	11.10
HI-LO	1.70	2.80	7.30	10.10
Q3-Q1	0.70	0.75	1.00	0.90
N	36	36	36	36
Group	B	C	D	A

Note. $H = 53.94$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	1.00	2.20	1.80
Q1	1.10	1.90	2.70	2.05
Q2 (Median)	1.50	2.10	3.60	2.60
Q3	2.30	2.75	4.20	3.55
HI Score	3.20	6.90	6.30	4.60
HI-LO	2.20	5.90	4.10	2.80
Q3-Q1	1.20	0.85	1.50	1.50
N	14	15	15	15
Group	B	C	D	A

Note. H = [illegible], p [illegible] .001 ($p = .001$ for $H > 16.27$)

Table C-27

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
CROSS-SECTIONAL VIEW: NUM-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	2.30	2.00	4.00
Q1	1.80	3.65	3.00	5.30
Q2 (Median)	2.15	5.00	3.35	6.05
Q3	3.00	7.60	4.25	7.25
HI Score	6.00	15.70	6.60	13.00
HI-LO	4.90	13.40	4.60	9.00
Q3-Q1	1.20	3.95	1.25	1.95
N	36	36	36	36
Group	C	D	A	B

Note. H = 89.34, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.90	3.80	4.00	4.90
Q1	2.90	4.90	4.25	6.10
Q2 (Median)	3.10	7.00	4.90	7.55
Q3	3.80	9.10	6.00	9.00
HI Score	5.00	11.10	9.60	28.10
HI-LO	3.10	7.30	5.60	23.20
Q3-Q1	0.90	4.20	1.75	2.90
N	15	15	15	14
Group	C	D	A	B

Note. H = 33.06, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-28

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
CROSS-SECTIONAL VIEW: NUM-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	2.80	1.80	2.70
Q1	2.00	3.80	2.80	4.90
Q2 (Median)	2.20	4.60	3.70	5.75
Q3	2.80	5.20	4.45	7.05
HI Score	3.80	7.00	6.20	10.20
HI-LO	2.50	4.20	4.40	7.50
Q3-Q1	0.80	1.40	1.65	2.15
N	36	36	36	36
Group	D	A	B	C

Note. $H = 84.07$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.20	3.20	2.90	4.20
Q1	2.95	4.45	3.60	5.15
Q2 (Median)	3.30	5.60	4.15	6.00
Q3	4.15	7.45	4.90	7.10
HI Score	14.00	9.10	6.90	9.30
HI-LO	11.80	5.90	4.00	5.10
Q3-Q1	1.20	3.00	1.30	1.95
N	15	15	14	15
Group	D	A	B	C

Note. $H = 24.41$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-29

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
CROSS-SECTIONAL VIEW: N/N-SEQ

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.80	0.50	1.00
Q1	1.50	1.45	1.35	1.70
Q2 (Median)	2.00	1.80	2.00	2.05
Q3	2.20	2.60	2.60	2.65
HI Score	4.00	4.80	11.10	3.60
HI-LO	3.00	4.00	10.60	2.60
Q3-Q1	0.70	1.15	1.25	0.95
N	36	36	36	36
Group	A	B	C	D

Note. H = 2.4, p > .05 (p = .05 for H > 7.82)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	1.80	1.10	1.50
Q1	2.00	2.20	1.80	2.20
Q2 (Median)	2.30	2.85	2.00	3.00
Q3	3.05	3.90	4.55	3.35
HI Score	5.20	4.80	10.70	6.10
HI-LO	3.50	3.00	9.60	4.60
Q3-Q1	1.05	1.70	2.75	1.15
N	15	14	15	15
Group	A	B	C	D

Note. H = 3.69, p > .05 (p = .05 for H > 7.82)

Table C-30

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
CROSS-SECTIONAL VIEW: N/N-RAN

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.80	0.80	1.00	1.70
Q1	1.90	1.20	2.05	2.85
Q2 (Median)	2.30	1.85	2.75	3.65
Q3	2.95	2.40	4.25	4.50
HI Score	8.60	4.00	12.70	12.00
HI-LO	7.80	3.20	11.70	10.30
Q3-Q1	1.05	1.20	2.20	1.65
N	36	36	36	36
Group	B	C	D	A

Note. $H = 37.45$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.10	1.60	2.50	1.90
Q1	2.30	2.20	3.05	3.50
Q2 (Median)	3.00	2.30	3.40	4.10
Q3	4.10	2.55	4.70	5.55
HI Score	5.10	3.90	6.50	7.00
HI-LO	3.00	2.30	4.00	5.10
Q3-Q1	1.80	0.35	1.65	2.05
N	14	15	15	15
Group	B	C	D	A

Note. $H = 24.04$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-31

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: SEQ/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.40	1.70	2.10	3.00
Q1	2.05	3.05	3.10	4.00
Q2 (Median)	2.60	3.60	3.20	4.35
Q3	3.00	4.25	4.00	5.05
HI Score	3.80	10.00	10.70	9.70
HI-LO	2.40	8.30	8.60	6.70
Q3-Q1	0.95	1.20	0.90	1.05
N	36	36	36	36
Group	C	B	A	D

<u>Note</u>. H = 69.68, $p < .001$ (p = .001 for H > 16.27)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.50	2.60	2.90	3.10
Q1	2.95	3.10	3.20	5.20
Q2 (Median)	3.00	4.30	4.00	6.00
Q3	3.90	5.10	4.70	8.00
HI Score	6.30	12.00	8.00	9.00
HI-LO	3.80	9.40	5.10	5.90
Q3-Q1	0.95	2.00	1.50	2.80
N	15	14	15	15
Group	C	B	A	D

<u>Note</u>. H = 23.39, $p < .001$ (p = .001 for H > 16.27)

Table C-32

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: SEQ/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.60	1.80	2.00	2.20
Q1	2.25	2.15	2.80	3.55
Q2 (Median)	2.95	2.45	3.20	3.90
Q3	3.60	3.00	3.60	4.30
HI Score	5.00	3.80	4.10	6.00
HI-LO	3.40	2.00	2.10	3.80
Q3-Q1	1.35	0.85	0.80	0.75
N	36	36	36	36
Group	D	C	B	A

Note. $H = 49.59$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.90	2.30	2.50	3.20
Q1	3.60	2.70	3.00	4.55
Q2 (Median)	3.90	3.20	3.60	5.00
Q3	4.15	3.95	4.30	6.00
HI Score	6.00	4.10	5.20	7.90
HI-LO	3.10	1.80	2.70	4.70
Q3-Q1	0.55	1.25	1.30	1.45
N	15	15	14	15
Group	D	C	B	A

Note. $H = 22.17$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-33

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: SEQ/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.60	2.00	2.00	2.60
Q1	2.70	3.05	2.30	3.40
Q2 (Median)	3.00	3.65	3.00	4.00
Q3	3.20	4.00	3.30	4.50
HI Score	4.60	5.00	4.90	10.50
HI-LO	3.00	3.00	2.90	7.90
Q3-Q1	0.50	0.95	1.00	1.10
N	36	36	36	36
Group	A	D	C	B

Note. $H = 41.64$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.20	2.80	3.00	3.60
Q1	3.10	3.85	4.00	4.20
Q2 (Median)	4.00	4.20	4.10	4.70
Q3	5.55	5.60	5.05	5.20
HI Score	7.10	7.80	8.30	7.90
HI-LO	4.90	5.00	5.30	4.30
Q3-Q1	2.45	1.75	1.05	1.00
N	15	15	15	14
Group	A	D	C	B

Note. $H = 5.51$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-34

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: SEQ/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.50	2.30	1.80	1.80
Q1	2.15	3.20	3.10	2.60
Q2 (Median)	2.85	3.85	3.60	3.00
Q3	3.20	4.90	4.10	3.45
HI Score	4.80	7.90	5.50	7.10
HI-LO	3.30	5.60	3.70	5.30
Q3-Q1	1.05	1.70	1.00	0.85
N	36	36	36	36
Group	B	A	D	C

Note. $H = 35.31$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.10	2.50	3.80	3.00
Q1	2.60	3.90	4.05	3.85
Q2 (Median)	3.15	4.90	4.30	4.10
Q3	4.00	7.35	5.45	4.75
HI Score	4.30	8.70	9.20	6.70
HI-LO	2.20	6.20	5.40	3.70
Q3-Q1	1.40	3.45	1.40	0.90
N	14	15	15	15
Group	B	A	D	C

Note. $H = 16.88$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-35

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: RAN/C/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	2.50	2.20	2.40
Q1	1.85	3.20	3.10	3.45
Q2 (Median)	2.20	3.85	3.65	4.05
Q3	2.80	4.00	4.15	4.55
HI Score	3.20	5.80	5.60	11.50
HI-LO	1.90	3.30	3.40	9.10
Q3-Q1	0.95	0.80	1.05	1.10
N	36	36	36	36
Group	B	A	D	C

Note. $H = 68.95$, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	3.10	3.20	4.00
Q1	2.50	3.50	4.40	4.55
Q2 (Median)	2.85	4.80	4.90	6.20
Q3	3.00	5.75	5.60	12.90
HI Score	4.90	7.60	7.00	19.70
HI-LO	3.20	4.50	3.80	15.70
Q3-Q1	0.50	2.25	1.20	8.35
N	14	15	15	15
Group	B	A	D	C

Note. $H = 30.66$, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-36

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: RAN/C/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	2.00	1.80	1.70
Q1	2.00	2.50	3.00	3.05
Q2 (Median)	2.45	3.00	3.75	3.60
Q3	3.00	3.20	4.10	4.25
HI Score	5.00	10.10	5.30	7.20
HI-LO	3.30	8.10	3.50	5.50
Q3-Q1	1.00	0.70	1.10	1.20
N	36	36	36	36
Group	A	D	C	B

<u>Note</u>. H = 40.36, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.20	3.00	3.20	3.00
Q1	2.25	3.45	3.80	3.80
Q2 (Median)	3.00	4.10	4.40	4.05
Q3	3.75	5.05	5.15	5.20
HI Score	6.00	8.10	6.10	7.30
HI-LO	3.80	5.10	2.90	4.30
Q3-Q1	1.50	1.60	1.35	1.40
N	15	15	15	14
Group	A	D	C	B

<u>Note</u>. H = 15.88, $p < .01$ ($p = .01$ for $H > 11.34$)

Table C-37

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: RAN/NC/E

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.30	2.30	2.50
Q1	1.80	2.60	2.55	3.60
Q2 (Median)	2.15	3.00	3.65	4.00
Q3	2.80	3.60	4.00	4.55
HI Score	4.00	4.90	5.60	6.00
HI-LO	2.70	3.60	3.30	3.50
Q3-Q1	1.00	1.00	1.45	0.95
N	36	36	36	36
Group	D	C	B	A

Note. H = 63.6, $p < .001$ ($p = .001$ for $H > 16.27$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	3.00	3.20	2.80
Q1	2.30	3.20	4.00	4.90
Q2 (Median)	2.90	3.50	4.50	6.30
Q3	4.00	4.10	5.60	7.35
HI Score	7.80	6.50	6.10	12.90
HI-LO	6.50	3.50	2.90	10.10
Q3-Q1	1.70	0.90	1.60	2.45
N	15	15	14	15
Group	D	C	B	A

Note. H = 20.52, $p < .001$ ($p = .001$ for $H > 16.27$)

Table C-38

Test Item Distribution Statistics
Task 3 (Tell Nomenclature of Marked Part)
EXPLODED VIEW: RAN/NC/NE

Sonar Technician Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.80	1.20	1.80	2.20
Q1	2.10	2.00	2.20	2.55
Q2 (Median)	2.85	2.50	2.90	3.10
Q3	3.55	3.15	3.45	3.90
HI Score	7.00	4.60	6.40	13.70
HI-LO	5.20	3.40	4.60	11.50
Q3-Q1	1.45	1.15	1.25	1.35
N	36	36	36	36
Group	C	B	A	D

Note. $H = 12.47$, $p < .01$ ($p = .01$ for $H > 11.34$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.80	2.70	2.20	3.10
Q1	3.00	2.90	3.05	3.55
Q2 (Median)	3.40	3.10	3.90	4.00
Q3	4.65	4.10	4.80	4.50
HI Score	11.70	4.70	7.10	6.80
HI-LO	8.90	2.00	4.90	3.70
Q3-Q1	1.65	1.20	1.75	0.95
N	15	14	15	15
Group	C	B	A	D

Note. $H = 5.08$, $p > .05$ ($p = .05$ for $H > 7.82$)

Table C-39

Test Item Distribution Statistics
Task 4 (Use Zone System to Point to Part Given Callout Number)
Exploded View--62 Callouts

Sonar Technician Sample

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	5.10	5.50	2.70	6.50
Q1	9.45	9.05	9.35	8.40
Q2 (Median)	11.90	12.15	12.60	11.16
Q3	18.90	16.50	16.60	12.50
HI Score	39.20	23.80	44.10	37.60
HI-LO	34.10	18.30	41.40	31.10
Q3-Q1	9.45	7.45	7.25	4.10
N	36	36	36	36
Group	A	B	C	D

Note. H = 5.07, p > .05 (p = .05 for H > 7.82)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	3.80	9.90	4.80	9.10
Q1	17.90	14.00	9.20	12.70
Q2 (Median)	22.20	16.55	19.30	17.60
Q3	35.70	22.70	34.80	24.90
HI Score	39.10	44.80	55.20	48.10
HI-LO	35.30	34.90	50.40	39.00
Q3-Q1	17.80	8.70	25.60	12.20
N	15	14	15	15
Group	A	B	C	D

Note. H = 1.12, p > .05 (p = .05 for H > 7.82)

Table C-40

Test Item Distribution Statistics
Task 5 (Use Zone System to Point to Part Given Nomenclature)
Exploded View--62 Callouts

Sonar Technician Sample

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	1.80	.50	1.60	3.60
Q1	7.60	4.70	8.00	11.35
Q2 (Median)	11.50	14.25	13.10	15.95
Q3	17.40	18.45	21.30	23.70
HI Score	56.60	45.20	81.10	62.40
HI-LO	54.80	44.70	79.50	58.80
Q3-Q1	9.80	13.75	13.30	12.35
N	36	36	36	36
Group	D	C	B	A

Note. $H = 5.40$, $p > .05$ ($p = .05$ for $H > 7.82$)

Combined Boiler Technician and Gunner's Mate Sample

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	5.10	6.90	7.00	4.60
Q1	8.60	19.00	13.30	14.50
Q2 (Median)	20.80	26.50	16.90	21.00
Q3	27.40	34.10	28.50	44.25
HI Score	68.70	50.80	51.30	67.80
HI-LO	63.60	43.90	44.30	63.20
Q3-Q1	18.80	15.10	15.20	29.75
N	15	15	14	15
Group	D	C	B	A

Note. $H = 2.44$, $p > .05$ ($p = .05$ for $H > 7.82$)