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An experimental sequence examining the effect of task type, memory condition, and display presentation type on performance time and error rate, using columnar table versus vertical bar graph versus line graph

Suparna Das
New Jersey Institute of Technology

ABSTRACT

An Experimental Sequence Examining The Effect of Task Type, Memory Condition, Display Presentation Type on Performance Time and Error Rate, Using Columnar Table Versus Vertical Bar Graph Versus Line Graph

Suparna Das, Master of Science, Computer & Information Science Department, 1991

Thesis Directed by: Dr. Richard Coll, Assistant Professor

A total of 126 subjects at various levels of school and a health related manufacturing firm participated in three experiments that compared Tables, Line graphs and Bar graphs forms of data presentation. The experiments were performed each consisting of a training task followed by answering some questions based on the presented material. The experimental series were presented to six groups. Group 1, 3, 5 viewed Line graphs, Tables or Bar graphs respectively while answering the questions while the other three groups answered questions based on memory of either Line graphs, Table or Bar graph presentation.

The independent variables were:

1) Memory Condition (View Condition and Recall Condition).

2) Task Type (Relational Information retrieval and Specific Information retrieval).

3) Display Presentation Type (Columnar Table and Vertical Bar Graph and Line Graph)

4) Complexity (Three levels).

Dependant Variables were:

1) Time to task completion and

2) Error Scores.

The statistically significant findings are:

1) There is no interaction between Task Type and Display Presentation type.

2) There is an interaction between Memory Condition and Display Presentation Type. Use of Tables produce better results with respect to time under memory condition VIEW both for relational and specific information retrieval. Use of Bar graphs on the other hand produce better results than Line graphs and Tables under memory condition RECALL with respect to error scores and time.

3) There was no statistical difference with respect to errors under memory condition VIEW (subjects answered questions while viewing data). However table use showed a consistent non-significant advantage versus Line and Bar graphs across all three experiments. Bar graph use showed significantly fewer errors under memory condition RECALL across all three experiments.

An Experimental Sequence Examining The Effect of Task Type, Memory Condition, and Display Presentation Type on Performance Time and Error Rate, Using Columnar Table Versus Vertical Bar Graph Versus Line Graph

by

Suparna Das

Thesis submitted to the Department of Computer and Information Science of the New Jersey Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Computer and Information Science.

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Title of Thesis:

An Experimental Sequence Examining The Effect of Task Type, Memory Condition, Display Presentation Type on Performance Time and Error Rate, Using Columnar Table Versus Vertical Bar Graph Versus Line Graph.

Name of Candidate : Suparna Das

: Master of Science in Computer & Information Science, 1991

Thesis and abstract Approval: _____ 05 21 1991

Dr. Richard Coll **Date**

Assistant Professor

Department of Computer & Information Science

New Jersey Institute of Technology

VITA

Name: SUPARNA DAS

Address:

Degree and Date to be Conferred: MSCIS, 1991

Date of Birth:

Place of Birth:

Collegiate institutions attended	Dates	Degree	Date of Degree
Birla Institute of Technology, Mesra, India	1984-1988	BSCIS	May 1988
New Jersey Institute of Technology	1989-1991	MSCIS	Oct. 1991

Major: Computer & Information Science

TO MY PARENTS

&

MY HUSBAND

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Chapter 1

INTRODUCTION

Review of Literature

With the rise in prominence of the MIS, a major question of vendors, information professionals and users alike concerns the relative merit of various forms of information presentation, on organizational decision making. While designing a computer based decision system one focus is on the manner in which data is presented. Mason and Mitroff [1973] suggested that "mode of presentation" is an important variable for present day research.

Bearing on decision making, however is one broad aspect of any information processing system, that of "summarization". Huber [1982] suggested that summarization can greatly reduce the cognitive or logistical load on the business units having to process information.

Chevrany & Dickson [1974] investigated the difference in performance associated with using raw data versus statistically summarized data as the controllable features of information system. Study revealed that the subjects receiving the summarized data had lower production costs and made better decisions. When small volumes of data are presented, however, there may be no statistically significant difference in cost between raw and summarized data [Senn and Dickson, 1974]. With small amounts of data, the manager can focus easily on

the right point. Summarization also aids in avoiding a common trap; decision makers see patterns even in randomly distributed time series data points. Summarized displays avoid the raw data display and thereby improve decision making.

At the same time summarization can be used to ensure that a sent message will have an impact on the receiver. The concept is a reasonable one and is in fact an integral part of the messaging policy of many organizations. Initial direction towards messaging and its various aspects were suggested by Bandopadhay [1977] who stated that investigators of the time might do well to consider the total problem of evaluation of information for decision making rather than take a simplified view of information flow. With regard to information, Daft & Lengel [1986] define a quality of information "richness" or its ability to change understanding within a reasonable (organizationally appropriate) length of time. Graphs are richer and so could be expected to prove better results than tables. Impersonally written documents and numeric documents are considered least rich due to their inability to allow for feedback. These types of documents, however are the stuff of MIS and any enhancements of their ability to convey the intended message or serve the dedicated purpose are a worthy cause for study.

The design of MIS presentation formats then is key in serving optimal support to managers in the decision making process [Davis, 1986].

Human abilities to integrate information and judge probabalistic information accurately are major factors which cause overload. There is an upper limit to the processing capacity of an individual. One strategy of coping with this limitation is to aggregate or summarize information by way of converting tabular data into graphs.

The same mechanism of summarization was found by Keen [1981]. Designing summarization capability into a MIS requires a consideration of the cognitive abilities of the users to which the information will be put. Managers have neither the time nor the inclination to memorize data. Craik and Lockhart [1972] suggested that

two types of rehearsal are possible, maintenance and elaborative but only elaborative rehearsal produces durable memories. Craik & Watkins [1973] further showed that it was the type of rehearsal and not the amount that determines memories durability. Thus, modes of presentation of information need to be utilized which facilitate elaborative processing by the user.

Work along these Lines have been done by Lusk & Kersnick [1979] who studied the effect of cognitive style and report format on task preference. Their results show that environmental factors i.e. the type of report format used affect the performance of subjects.

Although study of information processing has always been a topic of interest, research on graphical & tabular presentations has failed to yield a consistent result.

Henry C. Lucas [1981] conducted an experiment to investigate the impact of computer based graphics on decision making. The treatments included the use of hard copy terminals and five different types of displays on a CRT. The results of the experiment provide limited support for use of graphics presentation in an information systems.

William Remus [1984] conducted an experiment to compare the effect of graphical & tabular displays. When used for decision making and in a production scheduling problem both graphical and tabular aids yield equally costly decisions. When erratic components of decisions are reduced, the tabular aids outperformed the graphical aids.

Benbasat & Schroeder [1977] found that graphical reports reduced production costs and building of graphical reports in database systems was cheaper than that of tabular reports. But according to Lucas & Nielson [1980] use of graphics was not profitable in logistics.

Research by Tullis[1981], Umanath and Scamell[1988], Davis[1986], Benbasat[1977], Zmud[1978] have found graphic presentation to be superior to

Tables whereas Grace[1966], Remus[1984], Lucas[1981], Lusk and Kernsick[1979] have found the reverse. Ives[1982], Dickson, DeSanctis and McBride[1986] however found no differences.

Although large sums are spent by industries for the purchase of tabular and graphic display packages and although important decisions are regularly made based on data organized by means of such packages, little uncontested knowledge is available concerning the relative efficacy of Tables and various forms of graphs [Coll & Coll, 1990].

Recently there has been some notable advances in the field of Computer Graphics. This has helped in the development of systems which can produce graphical outputs easily. According to Benbasat[1985] subjects receiving graphical output decision aids had lowest costs and used the least numbered reports in coming to decision. Lusk and Kernsick[1979] found that graphical displays were rated significantly more difficult to use and understand than tabular displays. Zmud[1978] found managers preferred the graphical displays. The effectiveness of computer graphics varies as a function of task environment in which the user is operating. Task environment is the environment surrounding and including the primary users. The primary users consist of decision makers making decisions based on information output and intermediaries (like staff) who interpret output for users.

The objective when conducting this experiment was to investigate aspects of task environment with respect to the use of graphs and Tables.

According to Coll & Coll [1990] there are 16 variables which affect both user preference for an efficiency of specific types of Tables and graphs. Three of the variables presented are type of problem, education, training specialty and problem complexity. They recommend that research in area of display presentation(Tables/graphs) must rely on at least 2 factor experimentation. Results

need to be evaluated with respect to the existence and directions of interactions among factors investigated.

In our study working within this recommended research framework we examined jointly

1) 2 levels of Task Type

2) 3 levels of Display Presentation type

3) 2 levels of Memory Condition

4) 3 levels of Task Complexity

Test material consisted of vertical column Tables, vertical Bar graphs and Line graphs.

1. Task Type Variable

Encoding Specificity [Tulving, 1979] plays an important role in display presentation. An item can more likely be recalled if the organization of the circumstances surrounding the memory acquisition is recreated at the time of recall. According to Tulving and Osler[1968] the success of recall of an item depends on two factors: the amount and organization of the relevant information about the item in the store at the time of attempted recall and the number of retrieval cues which provide access to the stored information. Encoding Specificity has proven to be an extremely robust construct, applicable across a wide range of conditions and has been extended to activity involving recognition and analysis. Materials should be presented in the same form that it will be used.

Sometimes recall has been found superior to recognition despite the intuitive unexpectedness of this result.

As a prototypical experiment a series of sentences containing highlighted words are presented to subjects who are told to remember the highlighted words. Then the subjects are asked to recall the highlighted words. Here recall is usually 80

- 90 %. On providing them with another group of sentences containing no highlighted words in which the original words are embedded in different contexts recognition is usually 20%.

The above research suggests that better and quicker decisions can take place if the data is assimilated in the same form that it will be used in analysis. The format of the data should confirm to the structure of the problem.

Umanath and Scamell demonstrated this extension to encoding specificity in their experiment. Subjects were divided into 2 randomized groups and were exposed to a display presented either in a tabular form or a graphical form. Following this both groups were tested on their ability to recall information presented in the two display formats. The graphical form of presentation appears to be superior to tables for recall of pattern items recalled immediately. Results indicate that subjects were able to recall a good amount of information immediately. However their recall performance for specific information was poor for tabular stimuli in the delayed recall condition. Effectiveness of the graphical format on specific fact recall for immediate recall was negligible. Utility of graphs is therefore contingent upon the task at hand.

According to Jarvenpaa [1989] changes in presentation format can lead to changes in decision strategies used.

As far as our experiment is concerned the focus is on tasks involving requests for specific data values versus tasks involving requests for relational information. Based on the previous discussion we can say that responses to requests for specific value would be developed faster and more accurately by use of a table whereas responses to requests for relational value would be developed faster and more accurately by use of graphs because table data is specific in form while graph data is in relational form.

2. Memory Condition

In our experiment we had two memory conditions. One group had to answer questions by looking at the graphs and Tables whereas the other had to answer based upon memory. We would expect that subjects who had answered the questions from memory would have taken a longer time than the subjects who had answered the questions by looking at the Graphs. Subjects would have also taken a longer time to answer the relational information questions. With respect to error scores we would expect that subjects who had answered the questions from memory would have made more number of errors than the subjects who had answered the questions by looking at the graphs. Subjects would have also made more errors while answering the relational information questions

3. Display Presentation Type

According to some researchers graphs are a better mode of presentation whereas according to others tables are better. Some researchers of course have not found any difference. According to Fiske S. T., Taylor S. E.,[1984] use of tables were superior because they are more commonly used for data representation. On the other hand graphs proved superior when relational information was not available in tabular presentation. Knowledge about the relationship between the presentation format and the decision strategy can improve predictions of what type of presentation format support is most needed in a task at hand.

4. Problem Complexity Variable

We used three levels of complexity in our experiment to examine the development of factor effects along a complexity dimension. Dickson, DeSanctis and McBride[1986] suggest that graphic presentation is more effective than tables when large amounts of data is involved.

In our experiment the levels of complexity included:

Single Data Column/Single Line Graph/ Single Bar Graph

Double Data Column/Double Line Graph/ Double Bar Graph

Three Data Column/Three Line Graph/ Three Bar Graphs.

Chapter 2

METHOD

Subject

126 subjects were randomly assigned to 6 groups (22 subjects per group). Subjects in group 1, and 2 were tested with Line graphs. Subjects in group 3, and 4 were tested with tables. Subjects in group 5, and 6 were tested with Bar graphs.

The two groups, groups 1, 2 which were tested for Line graphs, we will reference as LV (Line graphs under memory condition VIEW) and LR (Line graphs under memory condition RECALL) respectively.

The two groups, groups 3, 4 which were tested for Tables, we will reference as TV (Tables under memory condition VIEW) and TR (Tables under memory condition RECALL) respectively.

The two groups, group 5, 6 which were tested for Bar graphs, we will reference as BV (Bar graphs under memory condition VIEW) and BR (Bar graphs under memory condition RECALL) respectively.

The six groups were evaluated for initial equivalence on the variable of age and years of computer experience. An ANOVA test on age and computer years yielded no difference for $p > 0.2$.

Material

The Tables, Line graphs and Bar graphs were created using Harvard Graphics.

Procedure

Subjects were tested individually, performing work at 3 successive levels of complexity.

The first step of business was filling out the personal profile questionnaire. Following this, the experimental work was performed.

Groups 2, 4 and 6 were told that they would be a given a practice test during which they would study the presentation material for 2 minutes. To aid help in memorizing activity they were given 5 typical questions to answer. After this they were given 2 minutes to study the material. After that the material was removed and they were given a set of 15 multiple choice questions to answer. These questions required specific value answers. Time was stopped as soon as the subject circled the 15th answer. Then they were given another set of 15 questions which required relational information answers. To avoid any serial effect, half of the subjects in each group received the specific questions first while the other half received the relational type of questions first. The subjects were however not informed about the type of questions. Once task I was over they were given task II and task III.

Groups 1, 3 and 5 were also told the same, the only difference being that they VIEWED the graphs while answering the questions. All timing was by stopwatch.

One point was deducted for each wrong answer. So for the 30 questions asked in each experiment the maximum number of errors a subject could make was 30.

Lastly, we administered an attitude test.

Complexity Level 1, Low Complexity

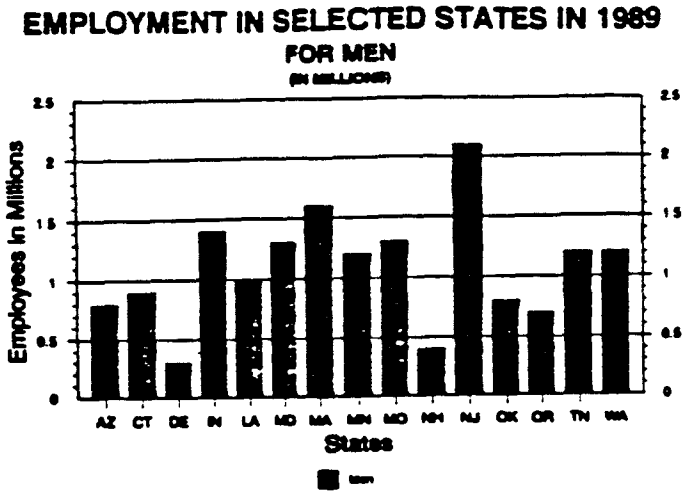
This complexity level utilized only 1 set of data values. The Line graph/Bar graph/table and a set of 4 questions are shown in Fig. 1. The first 2 questions requested specific values while the last two requested relational information.

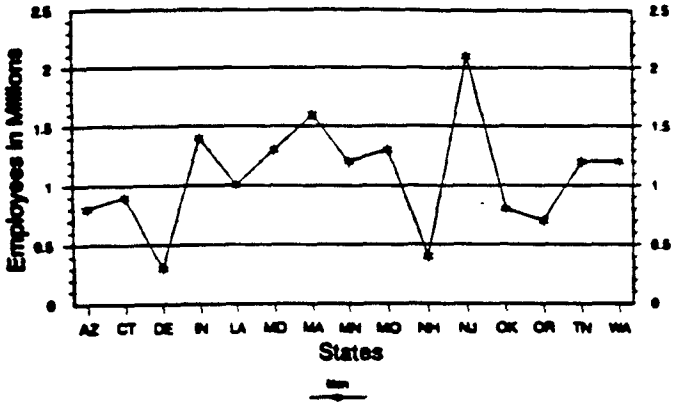
Complexity Level 2, Medium complexity

The procedure for this phase was identical to that of the previous complexity level. The Line graph/Bar graph/table and a set of 4 questions are shown in Fig. 2. However the material here was more complex in that it consisted of two data sets

Complexity level 3, High Complexity

The procedure for this phase was identical to that of the previous complexity level. This level however contained the most complex tasks in that it consisted of three data sets and more involved questions relating the three. The Line graph/Bar graph/Tables used in this experiment and 4 typical questions are shown in Fig. 3. The first 2 questions requested specific values while the last two requested relational information.





	Men
AZ	0.8
CT	0.9
DE	0.3
IN	1.4
LA	1.0
MD	1.3
MA	1.6
MN	1.2
MO	1.3
NH	0.4
NJ	2.1
OK	0.8
OR	0.7
TN	1.2
WA	1.2

FIG 1

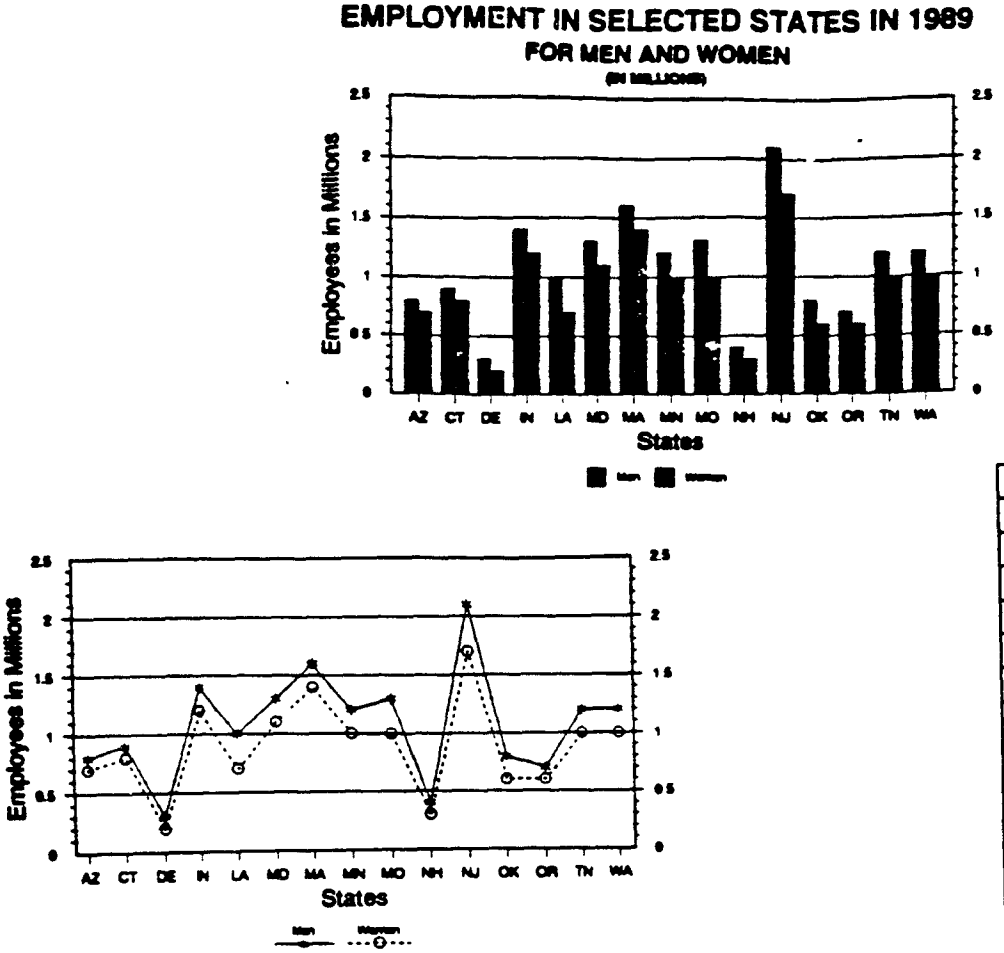
1. How many men are employed in NH?
a) 0.1 b) 0.2 c) 0.3 d) 0.4 e) 0.5

2) How many less men are employed in CT than in MN?
a) 0.7 b) 0.4 c) 0.2 d) 0.3 e) 0.5

3) From all the states starting with "M" which state has the least number of employed men?
a) MD b) MN c) OK d) MA e) DE

4. Which state has employed men than MA but more employed men than MO?
a) TN b) MD c) WA d) MO e) IN

Figure 1: Table, Bar Graph, Line Graph and four sample questions used at complexity level 1



	Men	Women
AZ	0.8	0.7
CT	0.9	0.8
DE	0.3	0.2
IN	1.4	1.2
LA	1.0	0.7
MD	1.3	1.1
MA	1 6	1.4
MN	1.2	1.0
MO	1.3	1.0
NH	0.4	0.3
NJ	2.1	1.7
OK	0.8	0.6
OR	0.7	0.6
TN	1.2	1.0
WA	1.2	1.0

FIG 2

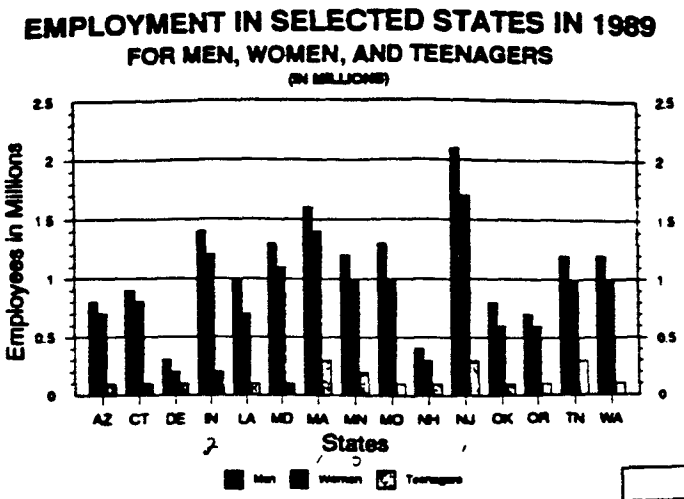
1. How many women are employed in WA?
   a) 2.0 b) 2.5 c) 1.0 d) 1.1 e) 1.2

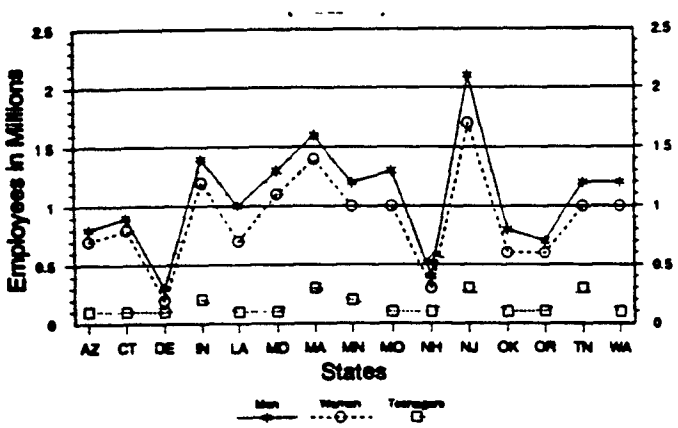
2) How many more women are employed in MA than in IN?
   a) 0.2 b) 0.3 c) 0.1 d) 0.5 e) 0.45

3) From all the states starting with "M" which state has the least number of employed women?
   a) IN b) MO c) DE d) OK e) OR

4. For all the states for which the number of employed men exceed 1.5 million, which state has the most employed women?
   a) MA b) IN c) NJ d) TN e) MD

Figure 2: Table, Bar Graph, Line Graph and four sample questions used at complexity level 2





	Men	Women	Teenagers
AZ	0.8	0.7	0.1
CT	0.9	0.8	0.1
DE	0.3	0.2	0.1
IN	1.4	1.2	0.2
LA	1.0	0.7	0.1
MD	1.3	1.1	0.1
MA	1.6	1.4	0.3
MN	1.2	1.0	0.2
MO	1.3	1.0	0.1
NH	0.4	0.3	0.1
NJ	2.1	1.7	0.3
OK	0.8	0.6	0.1
OR	0.7	0.6	0.1
TN	1.2	1.0	0.3
WA	1.2	1.0	0.1

FIG 3

1. Find the sum of employed men, women, teenagers in OK?
   a) 1.1 b) 1.2 c) 1.4 d) 1.3 e) 1.5

2) What is the total number of people employed in OR?
   a) 1.7 b) 1.9 c) 0.2 d) 1.1 e) 1.4

3) In how many states are all categories of employment greater than 0.2?
   a) 5 b) 4 c) 3 d) 1 e) 2

4. For all the states for which the number of employed teenagers is 0.2 which state has the largest number of employed men?
   a) NH b) IN c) MA d) LA e) TN

Figure 3: Table, Bar Graph, Line Graph and four sample questions used at complexity level 3

Attitude Test

Immediately following the conclusion of testing, each subject was given the six item attitude test shown below. To avoid any presentation bias attitude 1, 3, and 5 ascended in appeal while 2, 4, and 6 descended as shown.

1.....2.....3.....4.....5.....6.....7
EASY DIFFICULT

1.....2.....3.....4.....5.....6.....7
INEFFICIENT EFFICIENT

1.....2.....3.....4.....5.....6.....7
DESIRABLE UNDESIRABLE

1.....2.....3.....4.....5.....6.....7
COMPLICATED UNCOMPLICATED

1.....2.....3.....4.....5.....6.....7
HELPFUL HINDERING

1.....2.....3.....4.....5.....6.....7
FRUSTRATING SATISFYING

Chapter 3

EXPERIMENTAL DESIGN AND STATISTICAL TESTING

Design

We employed a between-group-within-group design with two between-group variables and two within group variables.

Between-Group Variables

1) Display Presentation Format (Table/Line graph/Bar graph).

2) Memory Condition (View/Recall).

Two Within-Group Variables

1) Task Complexity (Single, Double, and Triple data sets).

2) Task Type (Specific value response and Relational information response)

Statistical Testing and Questions of Interest

Across 12 statistical tests (6 using performance time and 6 using error scores) we examined the three levels of display presentation, two levels of Memory Condition, 2 levels of Task Type and three level of Task Complexity using repeated measures of ANOVA. Half of the subjects viewed the Tables, Line graphs or Bar graphs while answering the questions while the other half answered questions based on memory of either the Tables, Line graphs or Bar graphs. The subjects in the VIEW group were tested for performance time and error scores on each experiment.

Similarly the subjects in the RECALL group were tested for performance time and error scores on each experiment. This scheme is shown pictorially in Figure 4.

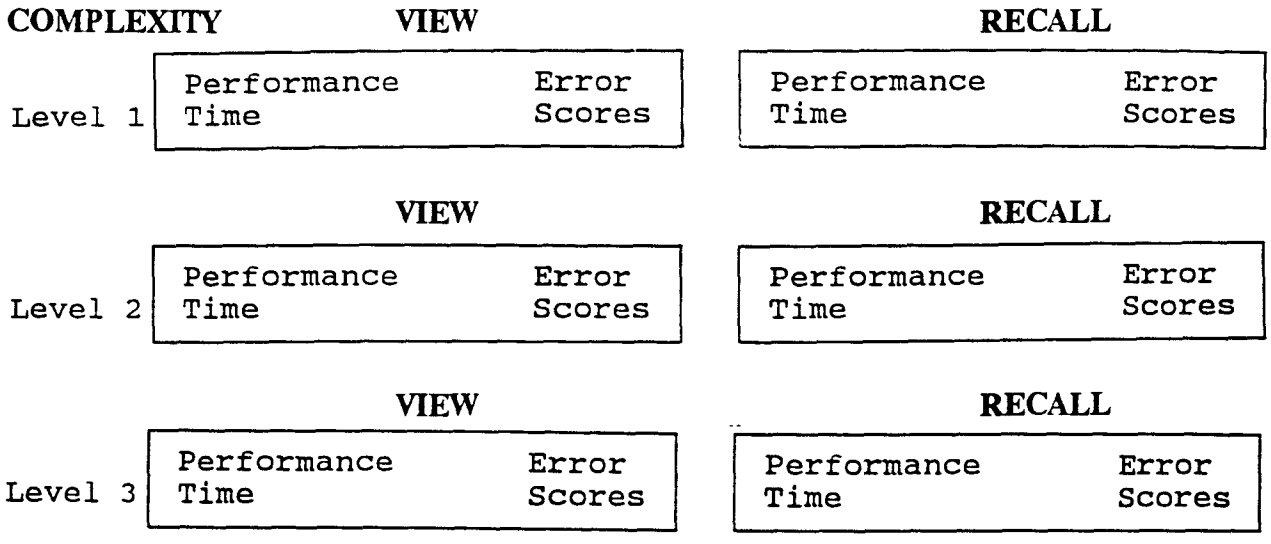


Figure 4

Specifically our questions were:

1) Is there a Task Type - Display Presentation interaction at each level of complexity for memory condition VIEW ?

2) Is there a Task Type - Display Presentation interaction at each level of complexity for memory condition RECALL ?

3) Is there a Memory Condition - Display Presentation interaction at each level of complexity?

Two sets of repeated measures ANOVA were run, one on dependent variable task time and another on dependent variable Error Scores.

At the end of the experimental sequence we performed an attitude test on each subject and summing across all six attitude scores to get a total value for each subject. We performed a one way analysis of variance on attitude with respect to the 6 groups.

Chapter 4

RESULTS

Below we examine differences among Display Presentation Type with respect to task time and error scores. We also examine Display Presentation Type - Task Type (Specific value, Relational information) interactions. However we cannot look for differences among the two levels of task type because the specific value questions are (of course) different than the relational information questions and therefore differences could be attributable to the wording of the question as well as or instead of the type of question, for example our relational information question may have been worded in a more complicated way than our specific value question.

Memory Condition - VIEW

Complexity Level 1, Low Complexity

The performance times for the three groups for the low complexity condition are shown in Figure 5A.

Group	Specific Value	Relational Information	Total Time
Table	281.2	298.7	579.9
Bar	328.7	336.8	665.5
Line	349.0	370.6	718.5

A: Average Time (seconds) for complexity level 1 and memory condition VIEW

Group	Specific Value	Relational Information	Total Errors
Table	2.2	1.9	4.1
Bar	3.5	2.1	5.6
Line	2.9	2.9	5.8

B: Average Error Score (# of errors) for complexity level 1 and memory condition VIEW

Figure 5: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 1.

A repeated measures ANOVA test found a significant difference among the three presentation conditions ($F(2,60) = 7.8$, $p < .001$). A Duncan Multiple Range test on performance time found that Tables group took less time than the Bar graph group and Line graph group while the Line graph group and Bar graph group were not different from each other ($p < .05$).

There was no interaction between the time taken to answer specific value questions and the time taken to answer the relational information questions across the three levels of Display Presentation ($p > .2$). These results are summarized in Figure 6A. The lack of interaction between variables is shown graphically in Figure 7A.

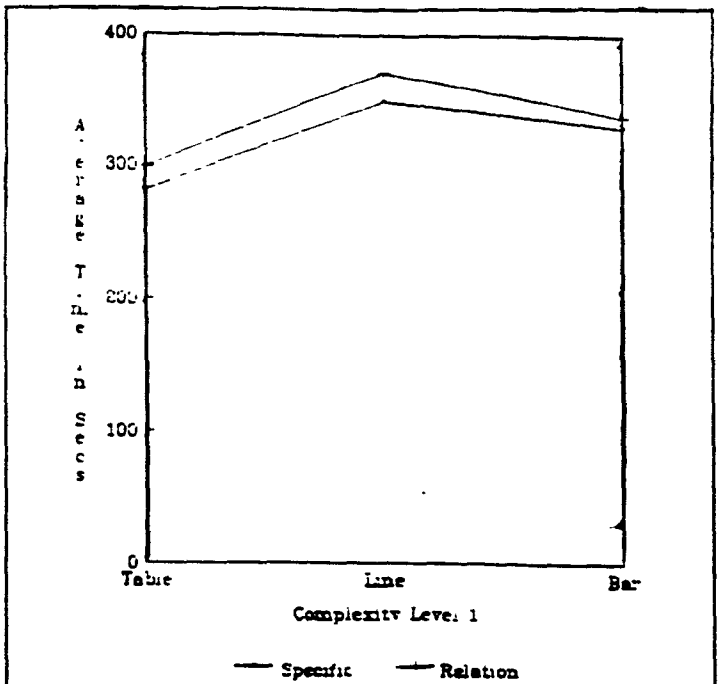
Factor	F	Significant	Duncan
Display Presentation	7.8	yes(p <.001)	T<B=L
Display Presentation by Task Type	.4	no (p >.2)	

A: Repeated measures ANOVA on Dependent Variable Performance Time for complexity level 1 and memory condition VIEW

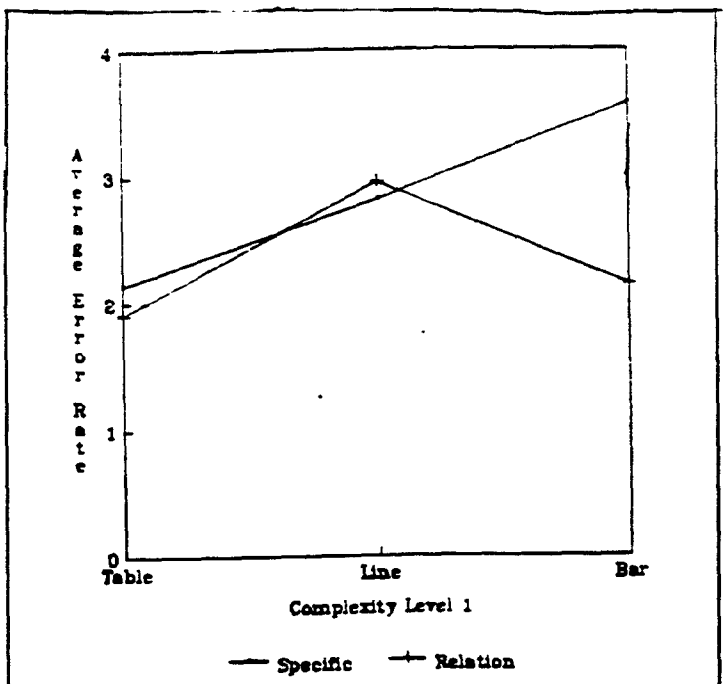
Factor	F	Significant
Display Presentation	1.78	no (p >.2)
Display Presentation by Task Type	4.88	yes(p <.05)

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 1 and memory condition VIEW

Figure 6: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 1.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 1 for memory condition VIEW



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 1 for memory condition VIEW

Figure 7: **Interaction Plots of Performance Time And Error Score Versus Display Presentation Type for Complexity Level 1.**

The average error scores for the 3 groups for complexity level 1 are shown in Figure 5B. A repeated measures Anova performed on the data did not find any significant differences among display presentation type ($p > .2$). However there was an interaction ($p < .05$). These results are summarized in Figure 6B. As the interaction plot for error (Figure 7B) shows, the locus of the interaction is in the Bar groups condition where specific value questions produced more errors relative to the relational information questions while in the other two conditions both specific value questions produced approximately the same amount of errors.

Complexity Level 2, Medium Complexity

The performance times for the three groups for the medium complexity condition are shown in Figure 8A.

Group	Specific Value	Relational Information	Total Time
Table	293.6	325.4	619.0
Bar	379.5	417.0	796.5
Line	373.7	384.4	758.1

A: Average Time (seconds) for complexity level 2 and memory condition VIEW

Group	Specific Value	Relational Information	Total Errors
Table	2.4	2.6	5.0
Bar	3.0	3.3	6.3
Line	2.6	2.8	5.4

B: Average Error Score (# of errors) for complexity level 2 and memory condition VIEW

Figure 8: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 2.

A repeated measures ANOVA test found a significant difference among the three presentation conditions ($F(2,60) = 14.12$, $p < .001$). A Duncan Multiple Range test on performance time found that Tables group took less time than the Bar graphs group and Line graphs group while the Line graphs group and Bar graphs group were not different from each other ($p < .05$).

There was no interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results (which are the same for complexity level 1) are summarized in Figure 9A. An interaction plot for task type versus display type is shown in Figure 10A.

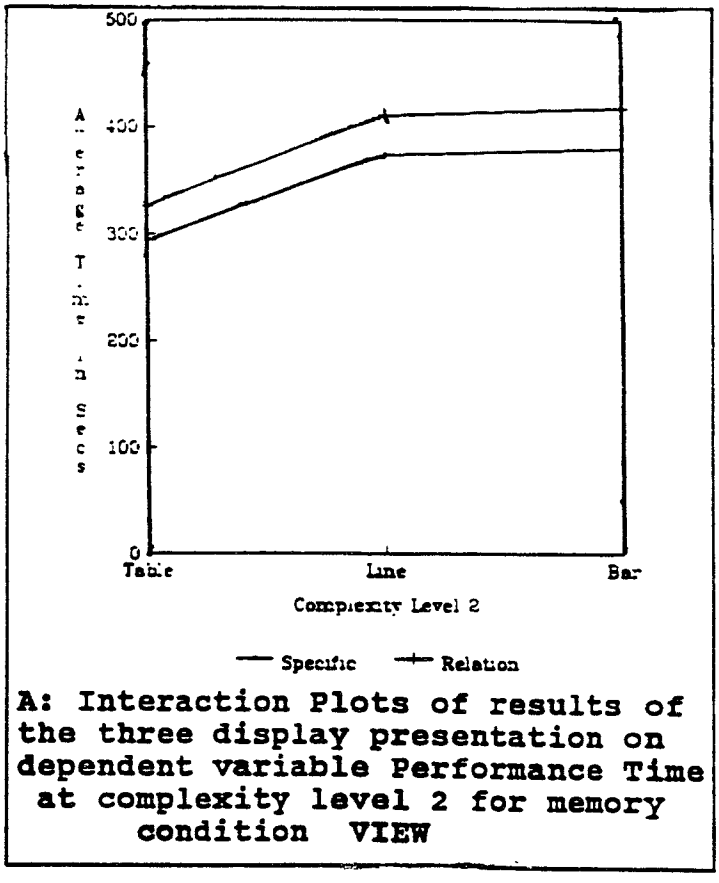
Factor	F	Significant	Duncan
Display Presentation	14.12	yes(p <.001)	T<B=L
Display Presentation by Task Type	.07	no (p >.2)	

A: Repeated measures ANOVA on Dependent Variable Performance Time for complexity level 2 and memory condition VIEW

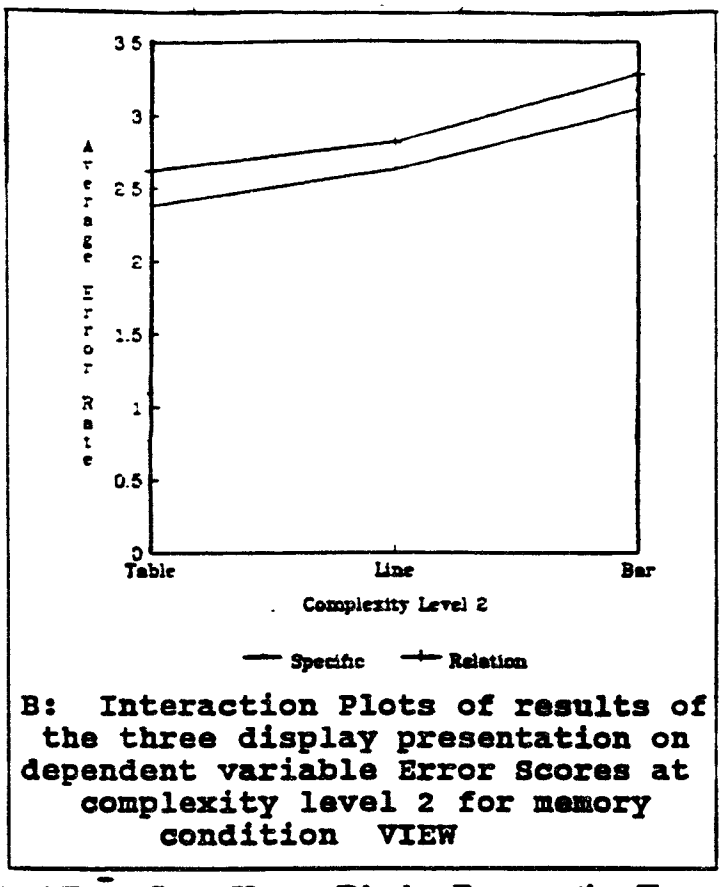
Factor	F	Significant
Display Presentation	1.36	no (p >.2)
Display Presentation by Task Type	.00	no (p > .2)

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 2 and memory condition VIEW

Figure 9: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 2.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 2 for memory condition VIEW



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 2 for memory condition VIEW

Figure 10: Interaction Plots of Performance Time And Error Score Versus Display Presentation Type for Complexity Level 2.

The average error scores for the three groups for complexity level 2 are shown in Figure 8B. A repeated measures ANOVA performed on the data did not find any significant difference among presentation type ($p > .2$). There was no interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results are summarized in Figure 9B. An interaction plot for task type versus display type is shown in Figure 10B. As the interaction plot shows, both specific value questions and relational information questions produced approximately the same amount of errors across all three groups.

Complexity Level 3, High, Complexity

The performance time for the three groups for the high complexity condition are shown in Figure 11A.

Group	Specific Value	Relational Information	Total Time
Table	319.4	342.4	661.8
Bar	398.3	453.8	852.1
Line	391.0	438.6	829.6

A: Average Time (seconds) for complexity level 3 and memory condition VIEW

Group	Specific Value	Relational Information	Total Errors
Table	2.2	1.9	4.1
Bar	3.5	2.1	5.6
Line	2.9	2.9	5.8

B: Average Error Score (# of errors) for complexity level 3 and memory condition VIEW

Figure 11: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 3.

A repeated measure ANOVA test found a significant difference among the three presentation condition ($F(2, 60) = 11.03$, $p < .001$). A Duncan Multiple Range test on performance time found that Tables group took less time than the Bar graphs group and Line graphs group while the Line graphs group and Bar graphs group were not different from each other ($p < .05$).

There was no interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results (which duplicate the complexity levels 1 and 2) are summarized in Figure 12A. An interaction plot for task type versus display type is shown in Figure 13A.

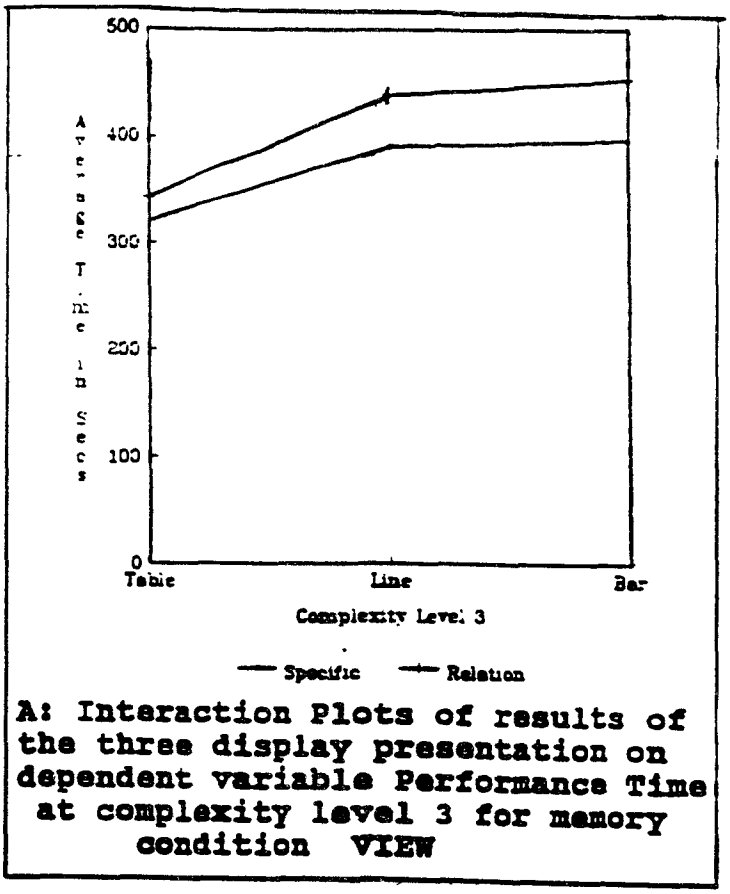
Factor	F	Significant	Duncan
Display Presentation	11.03	yes(p <.001)	T<B=L
Display Presentation by Task Type	.58	no (p >.2)	

A: Repeated measures ANOVA on Dependent Variable Performance Time for complexity level 3 and memory condition VIEW

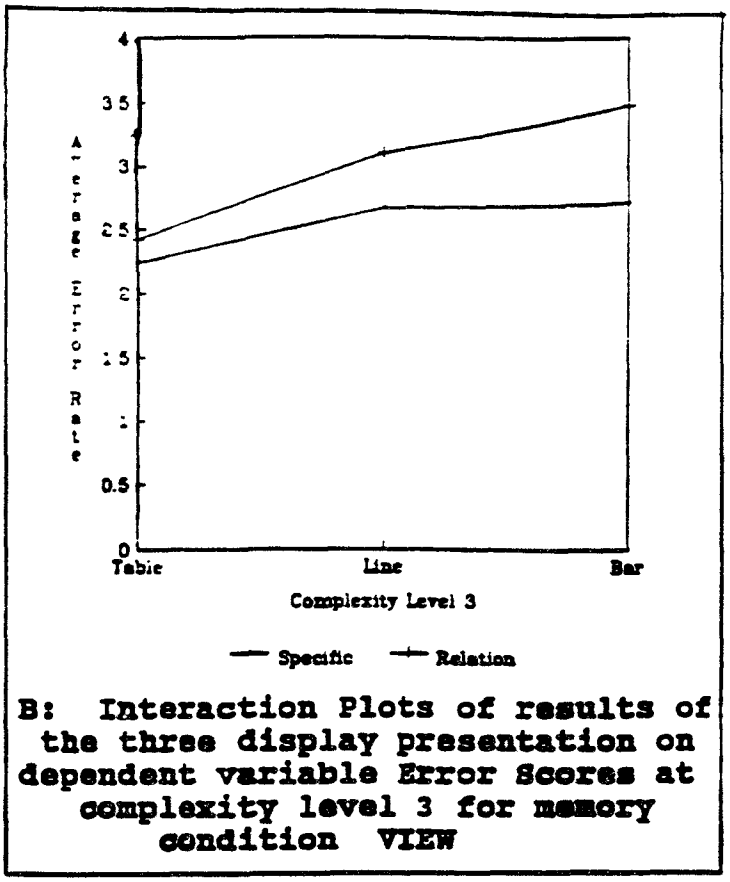
Factor	F	Significant
Display Presentation	1.52	no (p >.2)
Display Presentation by Task Type	.29	no (p >.2)

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 3 and memory condition VIEW

Figure 12: VIEW Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 3.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 3 for memory condition VIEW



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 3 for memory condition VIEW

Figure 13: Interaction Plots of Performance Time And Error Score Versus Display Presentation Type for Complexity Level 3.

The error scores for the three groups for complexity level 3 are shown in Figure 11. A repeated measures ANOVA performed on the data did not find any significant difference among presentation type ($p > .2$). There was no significant interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results are summarized in Figure 12B. An interaction plot for task type versus display type is shown in Figure 13B.

Results Summary - Across three levels of complexity

Under memory condition VIEW with respect to performance time Tables group across all three levels of complexity took less time than the Bar graph and Line graph groups while the Bar graphs group and Line graphs group were always not different from each other.

There was no significant difference among presentation type on dependent variable error scores. However Tables group showed a consistent non significant advantage versus Line and Bar graph groups across all three experiments.

Memory Condition Recall

Complexity Level 1, Low Complexity

The performance times for the three groups for the low complexity condition are shown in Figure 14A.

Group	Specific Value	Relational Information	Total Time
Table	419.2	403.0	829.2
Bar	319.2	302.6	621.8
Line	362.0	373.7	735.7

A: Average Time (seconds) for complexity level 1 and memory condition RECALL

Group	Specific Value	Relational Information	Total Errors
Table	6.4	6.3	12.7
Bar	4.5	4.4	8.9
Line	5.9	6.2	12.1

B: Average Error Score (# of errors) for complexity level 1 and memory condition RECALL

Figure 14: RECALL Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 1.

A repeated measures ANOVA test found a significant difference among its three presentation conditions ($F(2,60) = 9.56$, $p < .001$). A Duncan Multiple Range test on performance time found that Bar graphs group took less time than the Line graphs group which took less time than the Tables group ($p < .05$).

There is no interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results are summarized in Figure 15A. An interaction plot for task type versus display presentation is shown in Figure 16A.

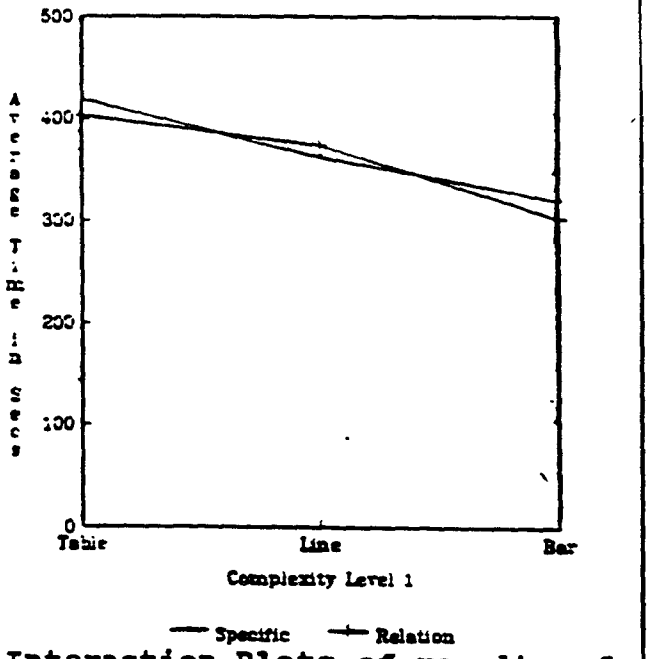
Factor	F	Significant	Duncan
Display Presentation	9.56	yes(p <.001)	B<L<T
Display Presentation by Task Type	1.81	no (p >.2)	

A: Repeated measures ANOVA on Dependent Variable Performance Time for complexity level 1 and memory condition RECALL

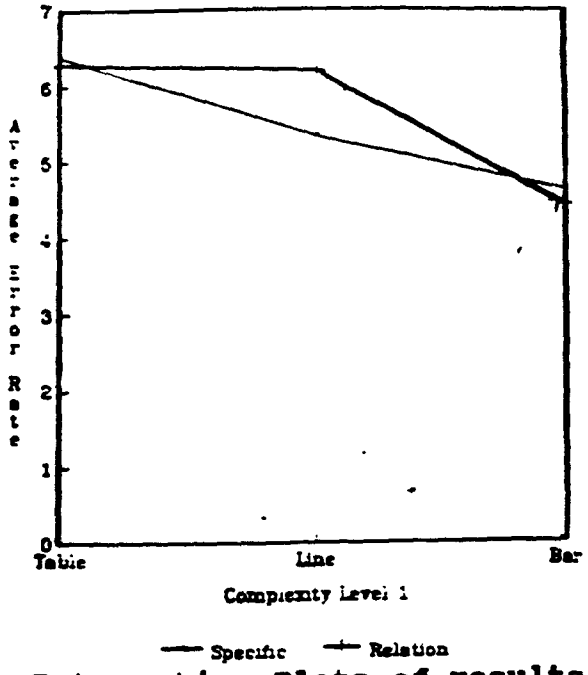
Factor	F	Significant	Duncan
Display Presentation	2.97	yes(p <.001)	B<L<T
Display Presentation by Task Type	2.07	no (p > .2)	

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 1 and memory condition RECALL

Figure 15: RECALL Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 1.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 1 for memory condition RECALL



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 1 for memory condition RECALL

Figure 16: Interaction Plots of Performance Time And Error Score Versus Display Presentation Type for Complexity Level 1.

The error scores for the three groups for complexity level 1 are shown in Figure 14B. A repeated measures Anova performed on the table found a significant difference among its three presentation conditions ($F(2,60) = 2.97$, $p < .001$). A Duncan Multiple Range test on error scores found that the error scores for Bar graph group was less than the error scores of Line graph group which was less than the error scores of the table group.

There is no interaction between task type and display presentation ($p > .2$). These results are summarized in Figure 15B. An interaction plot for task type versus display type is shown in Figure 16B.

Complexity Level 2, Medium Complexity

The performance times for the three groups for the medium complexity condition are shown in Figure 17A.

Group	Specific Value	Relational Information	Total Time
Table	423.9	432.6	856.5
Bar	316.5	364.7	681.2
Line	391.9	403.9	795.8

A: Average Time (seconds) for complexity level 2 and memory condition RECALL

Group	Specific Value	Relational Information	Total Errors
Table	6.8	7.3	13.1
Bar	4.7	4.2	8.9
Line	5.3	5.3	10.6

B: Average Error Score (# of errors) for complexity level 2 and memory condition RECALL

Figure 17: RECALL Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 2.

A repeated measures ANOVA test found a significant difference among the three presentation condition ($F(2,60) = 5.96$, $p < .001$). A Duncan Multiple Range test on performance time found that Bar graphs group took less time than the Line graphs group which took less time than the Tables group.

There was an interaction between task type (specific value and relational information) and display presentation ($p < .05$). These results are summarized in Figure 18A. An interaction plot for task type versus display type is shown in Figure 19A. The plots show, that the locus of this interaction was in the Bar graph condition, where specific value questions took less time to the relational information questions while in the other two conditions both specific value questions and relational information questions took approximately the same time.

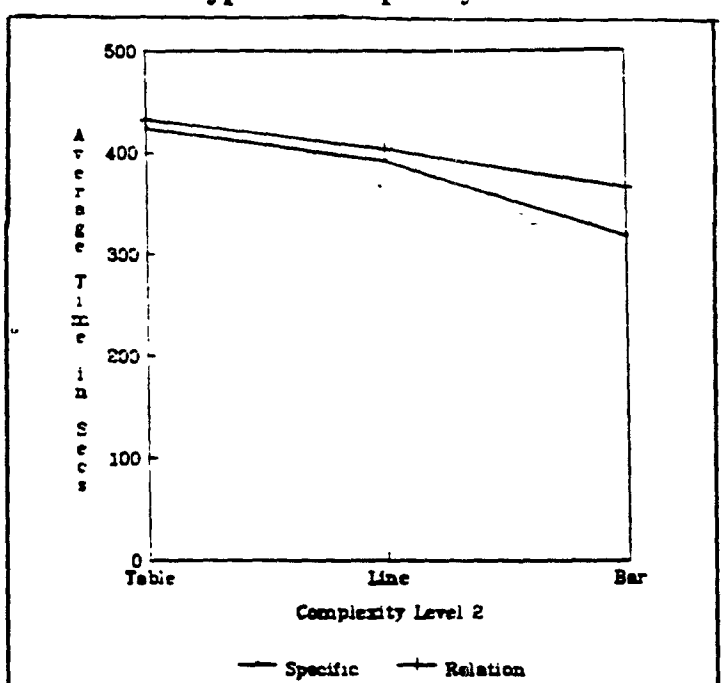
Factor	F	Significant	Duncan
Display Presentation	5.96	yes(p <.001)	B<L<T
Display Presentation by Task Type	6.05	yes(p <.05)	

A: Repeated measures ANOVA on Dependent Vatiable Performance Time for complexity level 2 and memory condition RECALL

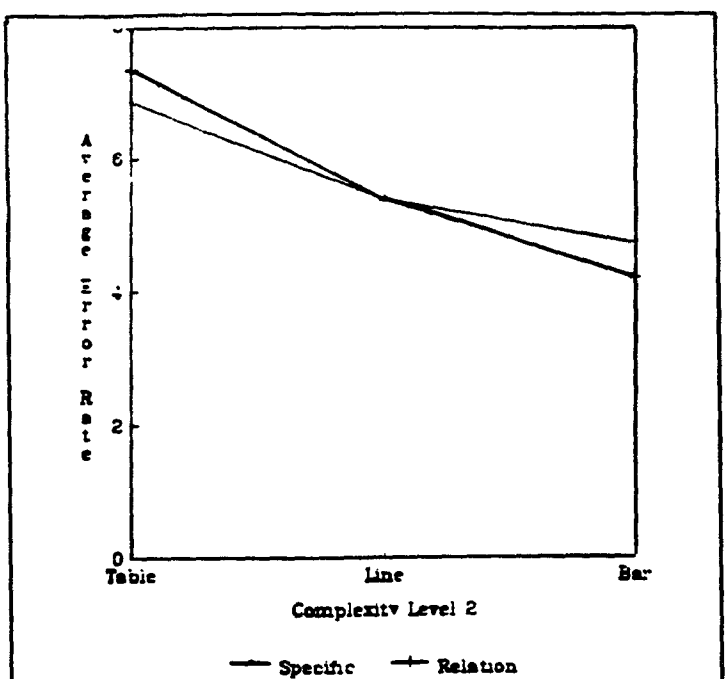
Factor	F	Significant	Duncan
Display Presentation	6.16	yes(p <.001)	B<L<T
Display Presentation by Task Type	1.18	no (p > .2)	

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 2 and memory condition RECALL

Figure 18: RECALL Condition - Performance Time and Error Score Versus Display Presentation Type for Complexity Level 2.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 2 for memory condition RECALL



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 2 for memory condition RECALL

Figure 19: Interaction Plots of Performance Time And Error Score Versus Display Presentation for Complexity Level 2.

The error scores for the three groups for complexity level 2 are shown in Figure 17B. A repeated measures ANOVA performed on the data found a significant difference among the three presentation conditions ($F(2,60) = 6.16$, $p < .001$). A Duncan Multiple Range test on error scores found that the error scores for

Bar graphs group was less than the error scores of Line graph group which was less than the error scores of the Tables group. There was no interaction between task type (specific value and relational information) and display presentation ($p > .2$). These results are summarized in Figure 18B. An interaction plot for task type versus display type is shown in Figure 19B.

Complexity Level 3, High, Complexity

The performance time for the three groups for the high complexity condition are shown in Figure 20A.

Group	Specific Value	Relational Information	Total Time
Table	425.6	460.2	885.8
Bar	351.4	347.7	699.1
Line	428.7	453.4	882.1

A: Average Time (seconds) for complexity level 3 and memory condition RECALL

Group	Specific Value	Relational Information	Total Errors
Table	7.5	6.8	14.3
Bar	3.9	4.9	8.8
Line	5.3	3.0	8.3

B: Average Error Score (# of errors) for complexity level 3 and memory condition RECALL

Figure 20: RECALL Condition - Performance Time and Error Score Versus Display Presentation e for Complexity Level 3.

A repeated measures ANOVA test found a significant difference among the three presentation condition ($F(2, 60) = 7.66$, $p < .001$). A Duncan Multiple Range test on performance time found that Bar graphs group took less time than the Line graphs group and the Tables group while the Line graphs group and Tables group were not different from each other ($p < .05$).

There in no interaction between task type and display presentation ($p > .2$). These results are summarized in Figure 21A. An interaction plot for task type versus display type is shown in Figure 22A.

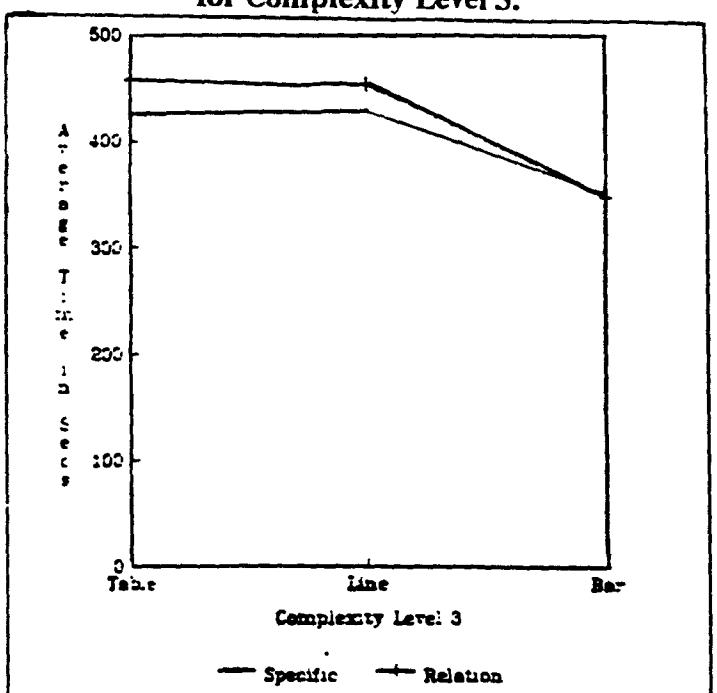
Factor	F	Significant	Duncan
Display Presentation	7.60	yes(p <.001)	B<L=T
Display Presentation by Task Type	2.62	no (p >.2)	

A: Repeated measures ANOVA on Dependent Variable Performance Time for complexity level 3 and memory condition RECALL

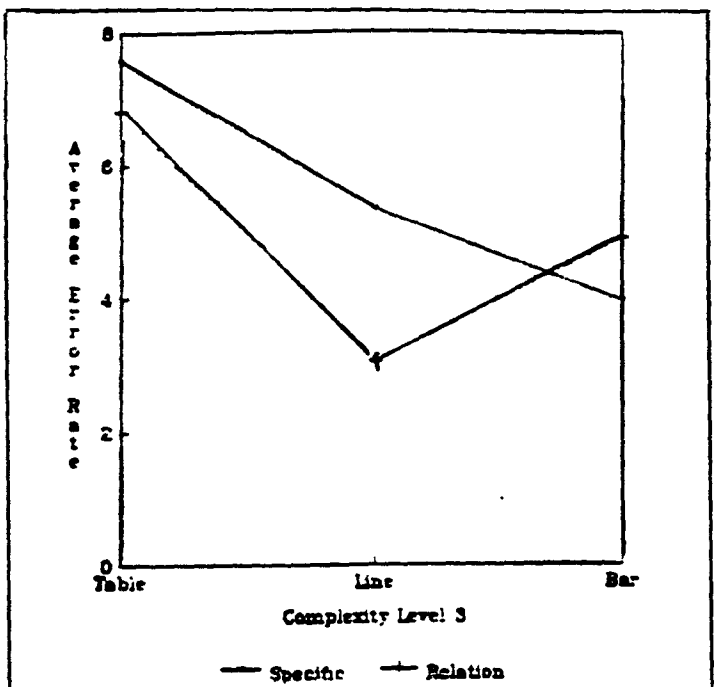
Factor	F	Significant	Duncan
Display Presentation	12.62	yes(p <.001)	B<L<T
Display Presentation by Task Type	.29	yes(p <.05)	

B: Repeated measures ANOVA on dependent variable Error Scores for complexity level 3 and memory condition RECALL

Figure 21: RECALL Condition - Performance Time and Error Score Versus Display Presentation for Complexity Level 3.



A: Interaction Plots of results of the three display presentation on dependent variable Performance Time at complexity level 3 for memory condition RECALL



B: Interaction Plots of results of the three display presentation on dependent variable Error Scores at complexity level 3 for memory condition RECALL

Figure 22: Interaction Plots of Performance Time And Error Score Versus Display Presentation Type for Complexity Level 3.

The error scores for the three groups for complexity level 3 are shown in Figure 20B. A repeated measures ANOVA performed on the data found a significant difference among presentation type ($p < .001$). A Duncan Multiple Range test on error scores found that the error scores for Bar graphs group was less

than the error scores of Line graph group which was less than the error scores of the Tables group.

There was an interaction between task type (specific value and relational information) and display presentation ($p < .05$). These results are summarized in Figure 21B. An interaction plot for task type versus display type is shown in Figure 22B. As the interaction plot for error shows, the locus of the interaction is in the Bar condition specific value questions produced fewer errors relative to the relational information questions while in the other two conditions specific value questions produced more errors relative to the relational information questions.

Results Summary - Across Three Levels of Complexity

Under memory condition RECALL with respect to performance time Bar graph use showed a significant advantage versus Line graph and Table groups across all three levels of complexity. Line graphs groups took significantly less time than the Tables groups across complexity levels 1 and 2 and showed a non significantly lower time at complexity level 3.

There was a significant difference among presentation type on dependent variable error scores. Bar graph groups showed a consistent significant advantage versus Line graph and Table groups across all three levels of complexity.

Use of Tables produce better results with respect to time under memory condition VIEW both for relational and specific information retrieval. Use of Bar graphs on the other hand produce better results than Line graphs and Tables under memory condition RECALL with respect to error scores and time.

View and Recall

The average total performance time for the six groups across all three levels of complexity are shown in Figure 23A.

Group	Average Total Time
Table View	1860.9
Bar View	2314.4
Line View	2333.8
Table Recall	2564.5
Bar Recall	2002.3
Line Recall	2314.9

A: Average Total Time for all six groups across all 3 levels of complexity

Group	Average Total Error Scores
Table View	13.7
Bar View	18.2
Line View	17.0
Table Recall	41.2
Bar Recall	26.7
Line Recall	30.6

B: Average Total Scores for all six groups across all 3 levels of complexity

Figure 23: Average Total Time and Average Total Error Score for Memory Condition Type Versus Display Presentation Type for all three levels of Complexity.

A 2 factor measures ANOVA test on Memory Condition Type versus Display Presentation Type found a difference on condition ($F(1, 120) = 4.7, p < .05$).

There in an interaction on time as shown in Figure 24A ($p < .05$). An interaction plot for Memory Condition versus Display Presentation Type on Performance Time is shown in Figure 25A.

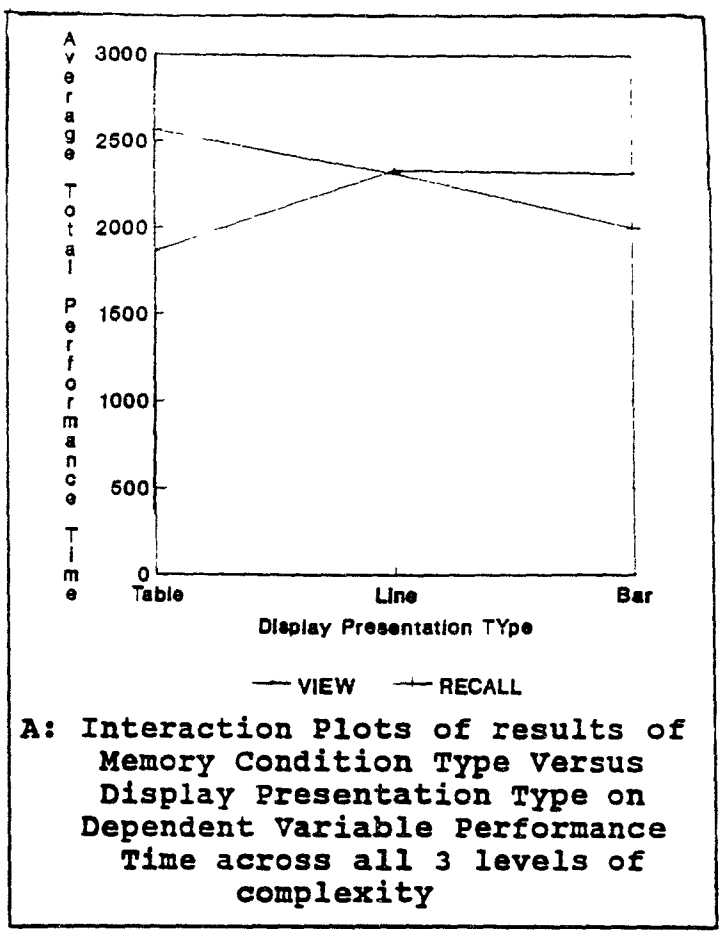
Factor	F	Significant	df
Memory Condition Type	4.70	yes(p <.05)	1,120
Memory Condition by Display Presentation Type	16.5	yes(p <.0001)	2,120

A: 2 factor ANOVA on Dependent Variable Performance Time across all 3 levels of complexity

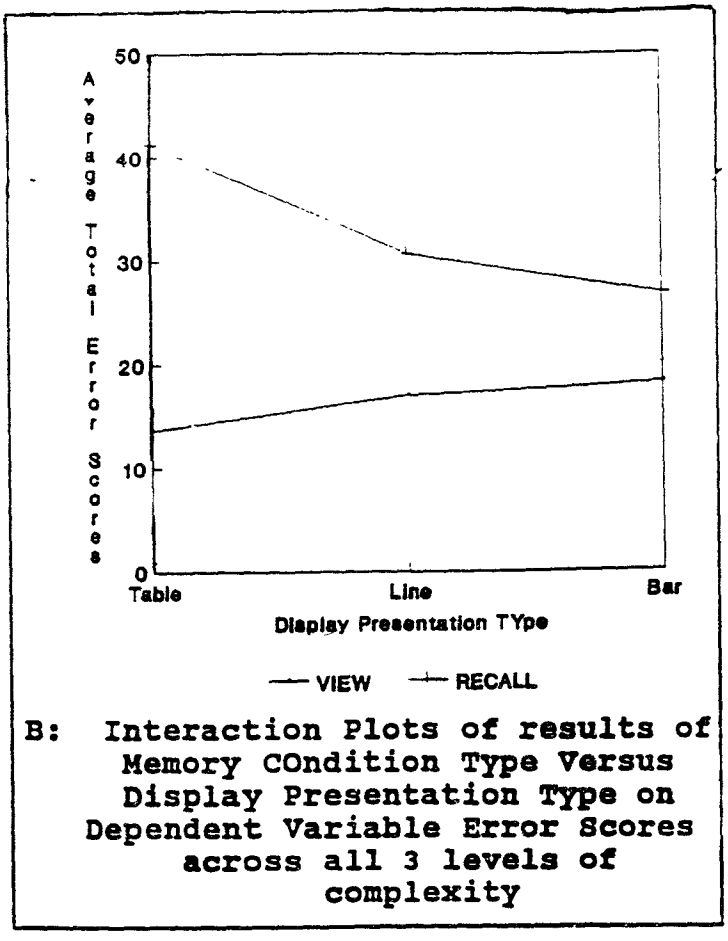
Factor	F	Significant	df
Memory Condition Type	74.22	yes(p <.0001)	1,120
Memory Condition by Display Presentation Type	8.8	yes(p <.0001)	2,120

B: 2 factor ANOVA on Dependent Variable Error Scores across all 3 levels of complexity

Figure 24: Average Total Performance Time and Average Total Error Score for Memory Condition Type Versus Display Presentation Type for all three levels of complexity.



A: Interaction Plots of results of Memory Condition Type Versus Display Presentation Type on Dependent Variable Performance Time across all 3 levels of complexity



B: Interaction Plots of results of Memory COndition Type Versus Display Presentation Type on Dependent Variable Error Scores across all 3 levels of complexity

Figure 23: Interaction Plots of Performance Time And Error Score for Memory Condition Versus Display Presentation Type for all three levels of Complexity

The average total error scores for the six groups across all three levels of complexity are shown in Figure 23B. A 2 factor measures ANOVA test on Memory Condition Type versus Display Presentation Type found a difference on condition ($F(1, 120) = 74.2, p < .0001$).

There in an interaction on time as shown in Figure 24B $p < .05$). An interaction plot for Memory Condition versus Display Presentation Type on Error Scores is shown in Figure 25B.

Attitude

A one way ANOVA test found a significant difference among the 6 groups ($F(3, 126) = 8.7$, $p < .00001$). Mean attitude scores are shown in Figure 26A.

A Duncan Multiple Range test on the data found specific differences ($p < .05$) as shown in Figure 26B. In Figure 26A each row presents conditions which were not significantly different from one and other. As Figure 26A shows, the condition for the best attitude score was Table group VIEWED. However Line Group though higher was not significantly different than this value (Duncan, $p < .05$).

Group	Memory Condition	Mean Attitude Rank
Table	View	12.45
Line	View	14.77
Bar	View	17.95
Bar	Recall	20.81
Line	Recall	21.86
Table	Recall	26.00

A: Mean Attitude Rank by group

Subset	Group
Subset 1	Table(View) Line Graph(View)
Subset 2	Bar Graph(View) Line Graph(View)
Subset 3	Bar Graph(View) Bar Graph(Recall Line Graph(Recall)
Subset 4	Line Graph(Recall) Table(Recall)

B: Duncan Multiple Range test results on the six different groups

Figure 26: Mean Attitude Rank by Group

Chapter 5

CONCLUSIONS

1. The most important finding of this study was an interaction between Display Presentation Type and Memory Condition. For Memory Condition VIEW use of Tables was significantly superior to use of Bar graphs and Line graphs with respect to performance time. For error scores while there was no significant difference among groups there was a consistent order effect in which the Tables error scores was always lower than the error rates of the other two conditions.

On the other hand for Memory Condition RECALL, for Performance Time use of Bar graphs was superior to use of Tables and Line graphs. For error scores use of Bar graphs was superior to use of Tables and Line graphs.

2. There was no interaction between Display Presentation and Task Type a finding in disagreement with the research by Umanath and Scamell (1988) and Coll, Thakur and Coll (1992).

3. Subjects preferred to use viewed data rather than memory data. They preferred to use Tables during Memory Condition VIEW and Bar Graphs during Memory Condition RECALL.

4. The results of Performance Time and Error Scores parallel the preferences exhibited by the subjects. For example in the VIEW condition Table use was superior to Line and Bar Graph use and, as well Table use was preferred to Line Graph use (difference not significant) and Bar Graph use (difference was significant). Similarly in the RECALL condition Bar Graph use was significantly better than use of the other two conditions for Performance Time and with respect to Error Scores never significantly worse than the other two conditions, as well, Bar Graph use was preferred to Line Graph use (difference not significant) and Table use (difference was significant).

Chapter 5

CONCLUSIONS

1. The most important finding of this study was an interaction between Display Presentation Type and Memory Condition. For Memory Condition VIEW use of Tables was significantly superior to use of Bar graphs and Line graphs with respect to performance time. For error scores while there was no significant difference among groups there was a consistent order effect in which the Tables error scores was always lower than the error rates of the other two conditions.

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