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OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: November 22, 1977

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Project No: G-36-624

Project Director: Dr. Albert N. Badre

Sponsor: U.S. Army Research Institute for the Behavioral & Social Sciences (PERI-RC); Alexandria, VA 22333

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SPONSORED PROJECT TERMINATION

Date: 8/3/78

Project Title: Selecting & Representing Information Structures for Battlefield Decision Systems

Project No: G-36-624

Project Director: Dr. Albert N. Badre

Sponsor: U.S. Army Research Institute for the Behavioral & Social Sciences (PERI-RC); Alexandria, VA 22333

Effective Termination Date: 7/3/78 (Grant Exp.)

Clearance of Accounting Charges: by 7/31/78

Grant/Contract Closeout Actions Remaining:

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Selecting and Representing Information Structures for Battlefield Decision Systems

Progress Report

Albert N. Badre

For
The U.S. Army Research Institute
for the Behavioral and Social Sciences

September 19 to November 30, 1977

Grant No.: DAHC19-77-G-0022

School of Information and Computer Science
Georgia Institute of Technology

December 8, 1977

Progress Report
on
Selecting and Representing Information Structures for Battlefield Decision Systems

The initial work on this project was focused primarily on reviewing the relevant and recent research on the representation of knowledge problem in both the areas of artificial intelligence and information processing psychology.* In surveying the artificial intelligence literature on knowledge representation the purpose was to identify various formal descriptions of information structures in order to use them as aids later in interpreting the empirical results of this research. The strategy used to achieve this goal was to explore and define the relationships between, on the one hand, higher order data-structures such as semantic networks and framelike systems, and, on the other hand, adaptive file-structures that permit the organization of information in a way that is meaningful to both the human processor and the file system.

It was concluded that relatively little work has been done to advance either the concepts or the design techniques of user-adaptive file structures. The reason for the lack of progress on the design of adaptive-file structures seems to be related to a fundamental lack of understanding and knowledge of how the human user, e.g., the human decision processor, organizes or structures the task-information. A brief review of the current cognitive psychology literature was hence undertaken in order to determine in a preliminary way what is known about human cognitive structuring and representation of task-information.

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*A list of references on the research work reviewed is provided in an addendum to this report.

In reviewing the research literature of the information processing psychology area, the main emphasis was placed on research that dealt with informational chunking in situations similar to that of the battlefield that require tactical and strategic decision processing and problem solving. More specifically the strategy was two-fold: (a) to search for evidence in the research literature that either supports or rejects the concepts of structuring and chunking in the process of representing information; and (b) to describe the experimental techniques used to collect such evidence leading to possible modifications in the proposed experimental methodology. The overall conclusion is that no empirical theory of knowledge representation has yet successfully described or explained in a generic way how a human chunks, aggregates, or structures the information in his task environment. The evidence however is strong that in decision-tasks knowledge is represented via informational chunking. Furthermore, the experimental techniques required to begin delineating some of the chunk characteristics for specific decision tasks were identified.

Work was also begun on the modification and completion of the experimental design. In this regard the principal investigator made a trip to the Army Research Institute in Alexandria, Va. where work on selecting a military subject sample and on the design of the material to be used in the experiment was initiated.

In the second quarterly phase of this project the plan is to complete the experimental design, conduct the experiment, and begin the data analysis.

The following research personnel have participated in the first phase of this project.

Principal Investigator:	Albert N. Badre
Graduate Research Assistant:	Elaine Strong Acree
Student Assistant:	Timothy Cope.

References

Amarel, S. Representations and modeling of problems of program formation. In B. Meltzer and D. Michie (eds), Machine Intelligence, Edinburgh: Edinburgh University Press, 1971.

Bobrow, D.G. Dimensions of representation. Representation and Understanding: Studies in Cognitive Science, New York: Academic Press, Inc., pp. 1-33, 1975.

Bobrow, D.G. et al. GUS, A frame-driven dialog system, Artificial Intelligence, Vol. 8, pp. 155-173, 1977.

Bobrow, D.G. and Norman, D.A. Some principles of memory schemata. Representation and Understanding: Studies in Cognitive Science, New York: Academic Press, Inc., pp. 131-149, 1975.

Bower, Gordon H. A selective review of organizational factors in memory. In E. Tulving and W. Davidson (eds), Organization of Memory, New York: Academic Press, Inc., pp. 93-137, 1972.

Broudy, H.S. Types of knowledge and purpose of education. In Anderson, Spiro, and Montague (eds), Schooling and the Acquisition of Knowledge, Hillside, N.J.: Lawrence Erlbaum Associates, 1977.

Buchanan, B. et al. Heuristic DENDRAL: A program for generating explanatory hypotheses in organic chemistry, Machine Intelligence 4, New York: American Elsevier, 1969.

Chase, W.G. and Simon, H.A. Perception in chess, Cognitive Psychology, Vol. 4, pp. 55-81, 1973.

Chase, W.G. and Simon, H.A. The mind's eye in chess. In W.G. Chase (ed), Visual Information Processing, New York: Academic Press, Inc., 1973.

Charness, N. Memory for chess positions: Resistance to interference, Journal of Experimental Psychology, Vol. 2, No. 6, pp. 641-653, 1976.

Charness, N. Human chess skill. In P. Frey (ed), Chess Skill in Man and Machine, New York: Springer-Verlag, 1977.

Davis, R. et al. Production rules as a representation for a knowledge based consultation program, Artificial Intelligence, Vol. 8, 1977.

DeGroot, A. Perception and memory versus thought: Some old ideas and recent findings. In B. Kleinmuntz (ed), Problem Solving: Research, Method, and Theory, New York: Wiley, 1966.

Dell'Orco, P. et al. Using knowledge of a data base world in interpreting natural language queries. IFIP Congress Proceedings, 1977.

Dirlam, D.K. Most efficient chunk series, Cognitive Psychology, Vol. 3, pp. 355-359, 1972.

Donovan, J.J. Database system approach to management decision support, ACM Transactions on Decision Systems, Vol. 1, No. 4, December 1976.

Frey, P.W. and Adesman, P. Recall memory for visually presented chess positions, Memory and Cognition, Vol. 4, No. 5, pp. 541-547, 1976.

Frey, P.W. (ed) Chess Skill in Man and Machine, New York: Springer-Verlag, 1977.

Good, I.J. A five-year plan for automatic chess, Machine Intelligence 2 New York: American Elsevier Publishing Co., Inc., 1968.

Hammond, K.R. and Summers, D.A. Cognitive control, Psychological Review, Vol. 79, No. 1, pp. 58-67, 1972.

Hearst, E. Man and machine: Chess achievements and chess thinking. In P. Frey (ed), Chess Skill in Man and Machine, ibid.

Kochen, M. Representations and algorithms for cognitive learning. Ann Arbor, Mich: Mental Health Research Institute, Preprint, 1973.

Kuipers, B.J. A frame for frames, representing knowledge for recognition. In Bobrow and Collins (eds), Representation and Understanding: Studies in Cognitive Science, Academic Press, 1975.

Minsky, M. A framework for representing knowledge. In P.H. Winston (ed), The Psychology of Computer Vision, New York: McGraw-Hill, 1975.

Nelson, K. Cognitive development and the acquisition of concepts. In Anderson, Spiro, and Montague (eds), Schooling and the Acquisition of Knowledge, ibid.

Quillian, M.R. Semantic memory. In Semantic Information Processing, Cambridge, Mass: M.I.T. Press, 1968.

Reitman, J.S. Skilled perception in GO: Deducing memory structures from inter-response times, Cognitive Psychology, Vol. 8, No. 3, pp. 336-356, July 1976.

Rumelhart, David E. and Ortony, Andrew. The representation of knowledge in memory. In Anderson, Spiro, and Montague (eds), Schooling and the Acquisition of Knowledge, ibid.

Salthouse, T.A. Number of memory representations in perceptual concepts, Journal of Experimental Psychology, Vol. 3, No. 1, pp. 18-28, 1977.

Samuel, A. L. Some studies in machine learning using the game of checkers II. Recent progress, IBM Journal of Research and Development, Vol. 11, No. 6, 1967.

Schank, R.C. Conceptual dependency: A theory of natural language understanding, Cognitive Psychology, Vol. 3, pp. 552-631, 1972.

Simmons, R. Semantic networks: Their computation and use for understanding English sentences. In R. Schank and K. Colby (eds), Computer Models of Thought and Language, San Francisco, Cal: W. H. Freeman, 1973.

Simon, H.A. and Gilmartin, K. A simulation of memory for chess positions, Cognitive Psychology, Vol. 5, pp. 29-46, 1973.

Winograd, T. Frame representations and the declarative/procedural controversy. In Bobrow and Collins (eds), Representation and Understanding: Studies in Cognitive Science, New York: Academic Press, Inc., pp. 185-210, 1975.

Selecting and Representing Information Structures for Battlefield Decision Systems

The Second Quarterly Progress Report

Albert N. Badre

For
The U.S. Army Research Institute
for the Behavioral and Social Sciences

December 1 to February 28, 1978

Grant No.: DAHC19-77-G-0022

School of Information and Computer Science
Georgia Institute of Technology

March 10, 1978

The Second Quarterly Progress Report
on

Selecting and Representing
Information Structures for Battlefield
Decision Systems

In the second phase of this project, the effort was concentrated on completing the experimental design and the design specifications for a data analysis program. In addition, several pilot runs of the experiment were conducted.

Completion of the experimental design included deciding on the location where military subjects will be tested, completing the design of the material to be used in the experiment, finalizing the details of the procedure, and selecting the data gathering instruments. On the whole, the general design as described in the proposal remained intact with the following modifications:

A. Twenty-four subjects will be selected to participate in the experiment. Twelve of these will be Georgia Tech students who have never been exposed to battlefield situations. The other twelve will be military commanders from Fort Benning, Georgia.

B. The material used in the experiment will consist of twelve reduced battlefield map displays. The maps have been selected on the basis of four categories of structuring. The first category contains three structured maps; ones that come out of real battlefield situations. The second category contains three maps that are semistructured in that while, in general, the situation is plausible, it is not likely to occur with frequency. The third category contains three unstructured maps; they are unstructured in that the occurrence of such situations is not possible on a real battlefield. The fourth category contains the same three maps as in the first category with the addition of the unit designators to each of the unit symbols. (A map example of each category is attached as part of this report).

C. A slide projector will be used to present the maps for viewing by the subject.

D. For the interplacement time recordings, a sound synchronizer (The Wollensack 255) will be used. This instrument will permit time recordings via a cassette beeper.

E. In order to record the symbols when reconstructing and copying, the subjects will be provided with rubber stamps of each of the eight symbols for both the red and blue colors.

F. The initial collected data will be analyzed via a special purpose computer program that is now being written. Examples of the outcome of this program are attached as part of this report.

G. The statistics to be run on the collected data are as follows:

1. CORRELATION ANALYSIS - The Correlation Analysis will be performed using SPSS's subprogram PEARSON CORR which computes Pearson product-moment correlations for pairs of variables.

   a) Interplacement Time (IPT) and Sequential Chunking Techniques will be correlated on the basis of the following variables:

      1) Types of Relations.

      2) Number of Pieces per chunk.

      3) Number of Relations per chunk.

      4) Chunk size as a function of chunk ordinal.

      5) Placement times.

      6) Ratio of Between chunk to within chunk placement times.

2. FREQUENCY ANALYSIS - The SPSS subprogram FREQUENCIES will be used to obtain for each group of subjects a count of the number of occurrences of the following:

   a) Types-of-relation frequencies of actual occurrence for different classes of boards.

   b) Type-of-relation frequencies as a function of chunk ordinal.

   c) Frequency of chunk size for different classes of boards.

   d) Frequency of chunk size as a function of chunk ordinal.

3. BATTLEFIELD RELATIONS PROBABILITIES - The a priori probabilities of the occurrence of different relations on the boards will be computed by summing the total number of relations of each type and dividing each sum by the total number of relations possible on the boards. The a priori probabilities will then be compared to the observed probabilities obtained from summing the observed occurrences of each type of relation and then dividing each sum by the total number of relations which have occurred.

The battlefield relation probabilities will then be correlated to show the relationship which exists between the glances of the Perception task and the time intervals of the Copying task (i.e. the within-glance probabilities would be related to the short time intervals, and the between-glance probabilities should be related to the long time intervals).

   a) Comparison of a priori probabilities and actual observed probabilities of the Perception and Copying tasks.

   b) Intercorrelation Matrix for comparison of probabilities between chunks and within chunks for the Perception and Copying tasks.

4. ACCURACY STATISTICS - RECONSTRUCTION TASKS - The accuracy statistics will be computed simply by summing the total number of pieces correctly placed on each board by each subject and dividing by the total number of pieces on the board.

   a) % accurately placed pieces averaged over each group of subjects and each board.

5. ANALYSIS OF VARIANCE (ANOVA) - The ANOVA will be performed using SPSS's Subprogram ANOVA. The ANOVA will be done to show the effect of experience on:

   a) Number of pieces placed per board

   b) Number of relations per board

   c) Number of chunks per board

In the final phase of this project, the plan is to conduct the experiment, complete the data analysis, and finish the final report.

The following research personnel have participated in the second phase of this project.

Principal Investigator:	Albert N. Badre
Graduate Research Assistant:	Elaine Strong Acree
Student Assistant:	Timothy Cope

5

CORRELATION OF IPT AND SEQUENTIAL CHUNKING TECHNIQUES

MAP POSITIONS

		STRUCTURED	STRUCTURED WITH UNIT DESIGNATORS	SEMI STRUCTURED	UNSTRUCTURED
NOVICES	TYPES OF RELATIONS				
	NUMBER OF PIECES PER CHUNK				
	NUMBER OF RELATIONS PER CHUNK				
	CHUNK SIZE AS A FUNCTION OF CHUNK ORDINAL				
EXPERTS	TYPES OF RELATIONS				
	NUMBER OF PIECES PER CHUNK				
	NUMBER OF RELATIONS PER CHUNK				
	CHUNK SIZE AS A FUNCTION OF CHUNK ORDINAL				

CORRELATION OF PLACEMENT TIMES FOR IPT AND SEQUENTIAL CHUNKING TECHNIQUES

MAP POSITIONS

		STRUCTURED	STRUCTURED W/Unit Designators	SEMISTRUCTURED	UNSTRUCTURED
NOVICES	PLACEMENT TIMES				
	RATIO OF BETWEEN CHUNK TO WITHIN CHUNK TIMES				
EXPERTS	PLACEMENT TIMES				
	RATIO OF BETWEEN CHUNK TO WITHIN CHUNK TIMES				

BOARD ACCURACY

BOARD		RECONSTRUCTION TASK ONE		RECONSTRUCTION TASK TWO	
		NOVICES	EXPERTS	NOVICES	EXPERTS
RUCTURED	1				
	2				
	3				
RUCTURED th IT SIGNATORS	4				
	5				
	6				
MISTRUCTURED	7				
	8				
	9				
STRUCTURED	10				
	11				
	12				

ACCURACY AVERAGES

	RECONSTRUCTION TASK ONE				RECONSTRUCTION TASK TWO			
	STRUCTURED	STRUCTURED W/ UNIT DESIGNATR	SEMI-STRUCTURED	UN-STRUCTURED	STRUCTURED	STRUCTURED W/ UNIT DESIGNATR	SEMI-STRUCTURED	UN-STRUCTURED
NOVICES								
EXPERTS								

COMPARISON OF TASKS

		ACCURACY			RELATIONS			NUMBER OF CHUNKS		
		C	R1	R2	C	R1	R2	C	R1	R2
Structured	NOVICE									
	EXPERT									
Structured with Unit Designators	NOVICE									
	EXPERT									
Semi-Structured	NOVICE									
	EXPERT									
Un-Structured	NOVICE									
	EXPERT									

A Comparison Of The Perception, Reconstruction, And

A Priori Battlefield Relation Probabilities

Battlefield Relations	WITHIN-GLANCE COPYING		WITHIN CHUNK RECONSTRUCTION		BETWEEN-GLANCE COPYING		BETWEEN CHUNK RECONSTRUCTION	
	Random	Actual	Task One	Task Two	Random	Actual	Task One	Task Two
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Inter-Correlation Matrix For The Copying, Reconstruction And A Priori Battlefield Relations Probabilities

1. Within-Glance (Random) } Copying
2. Within-Glance (Actual) } Copying
3. Less Than Chunk Boundary } Recons. Task One
4. Less Than Chunk Boundary } Recons. Task Two
5. Between Glance (Random) } Copying
6. Between Glance (Actual) } Copying
7. Greater Than Chunk Boundary } Recons. Task One
8. Greater Than Chunk Boundary } Recons. Task Two

1	2	3	4	5	6	7	8

FREQUENCY OF CHUNK SIZE FOR A GIVEN CLASS OF BOARD

BOARD CLASS

FREQUENCY OF CHUNK SIZE	STRUCTURED		STRUCTURED WITH DESIGNATR UNIT		SEMI-STRUCTURED		UNSTRUCTURED	
	EXPERT	NOVICE	EXPERT	NOVICE	EXPERT	NOVICE	EXPERT	NOVICE
1								
2								
3								
4								
5								
6								
7								

FREQUENCY OF RELATIONS

TASK COPYING

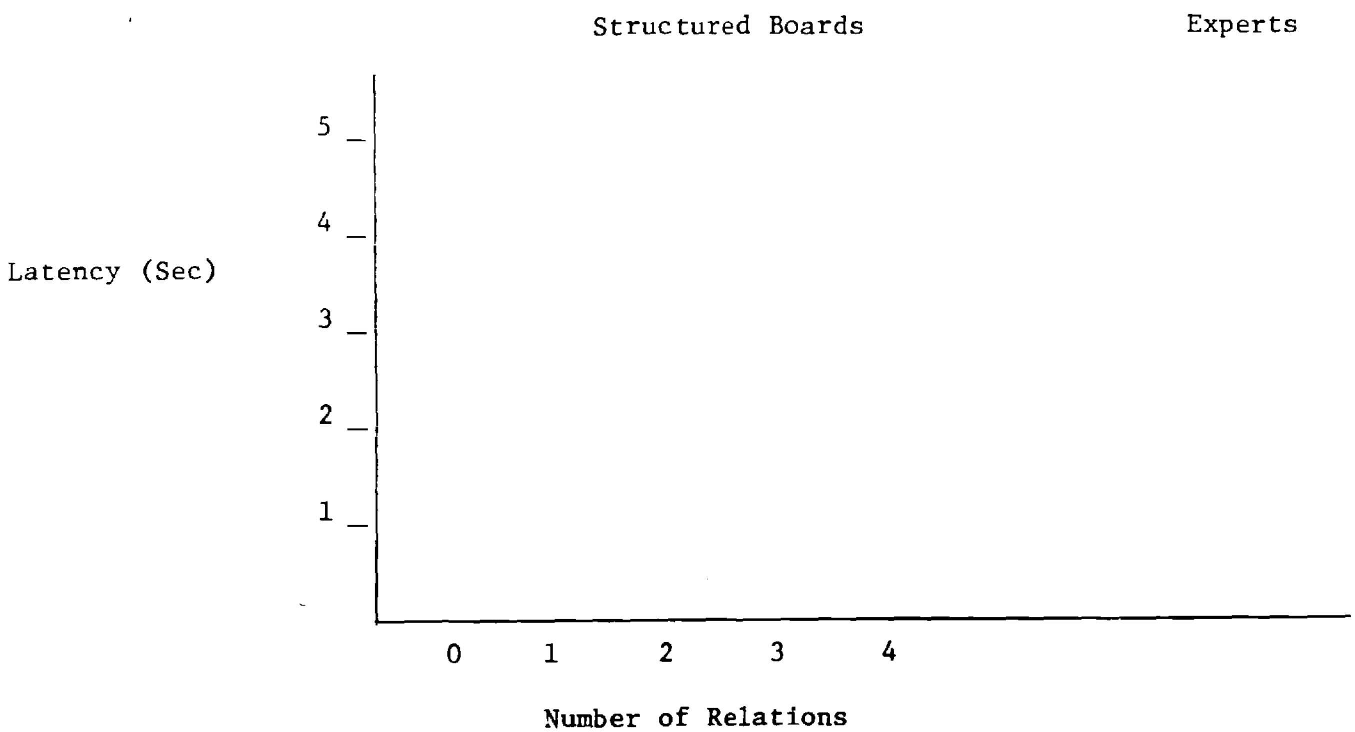
RELATION	EXPERT				NOVICE			
	STRUCTURED	STRUCTURED W/UNIT DESIGNATOR	SEMI-STRUCTURED	UNSTRUCTURED	STRUCTURED	STRUCTURED W/UNIT DESIGNATOR	SEMI-STRUCTURED	UNSTRUCTURED
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

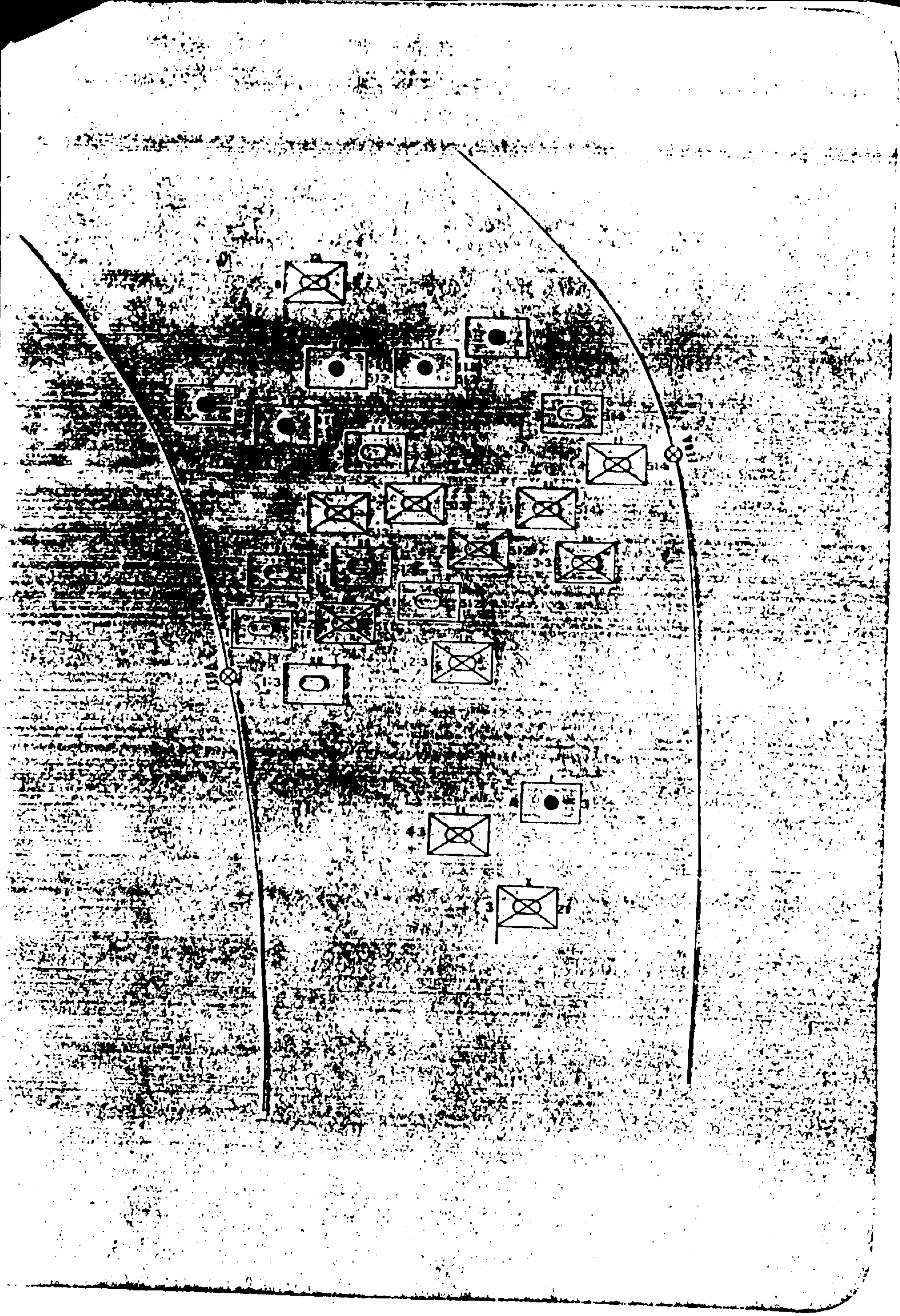
AVERAGE FREQUENCY OF CHUNK SIZE AS A FUNCTION OF CHUNK ORDINAL

CHUNK NUMBER	EXPERT	NOVICE	
1			
2			
3			
4			
5			
6			
7			

Interpiece Latency vs. Number of Relations

Between Pairs of Successively Placed Pieces





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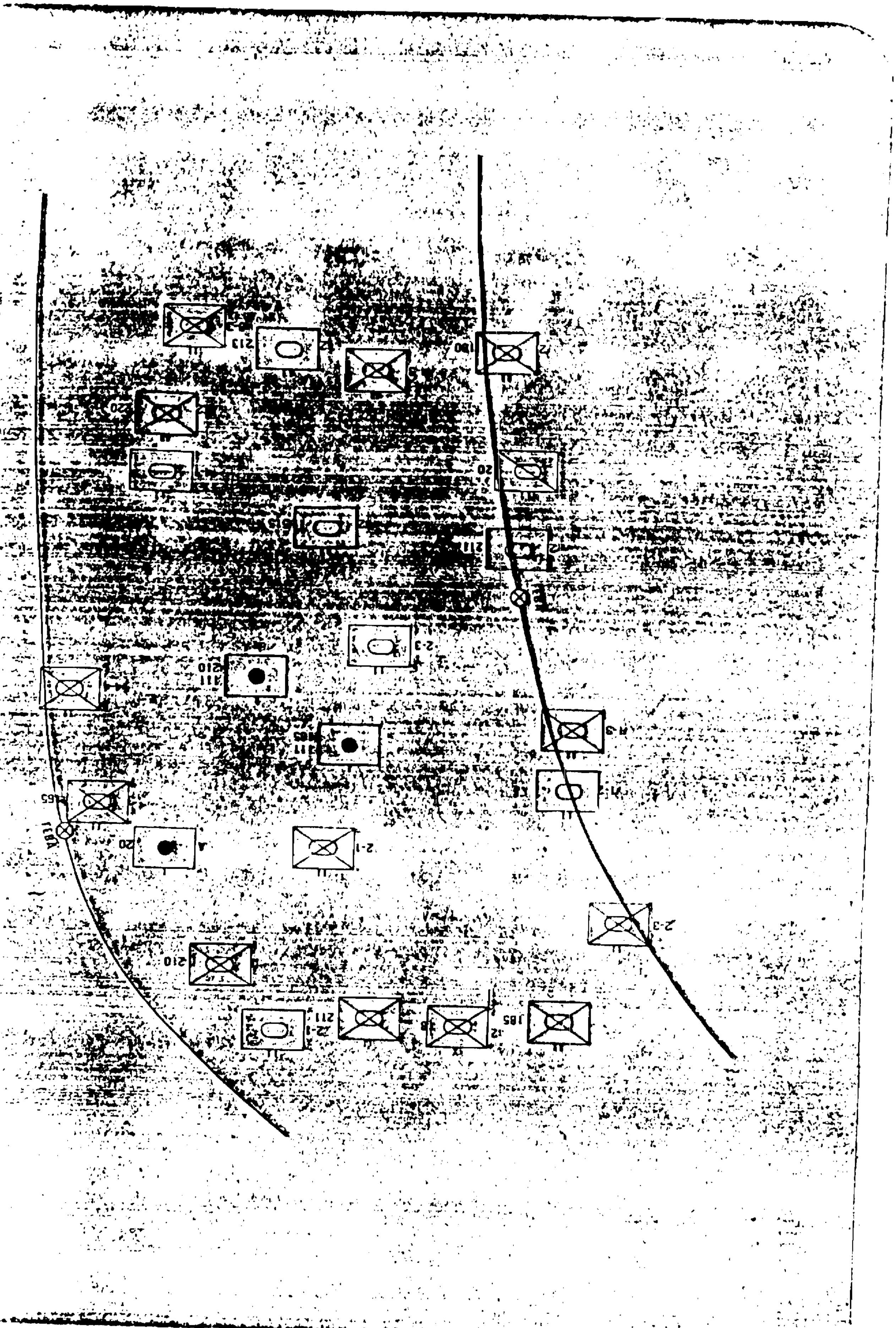

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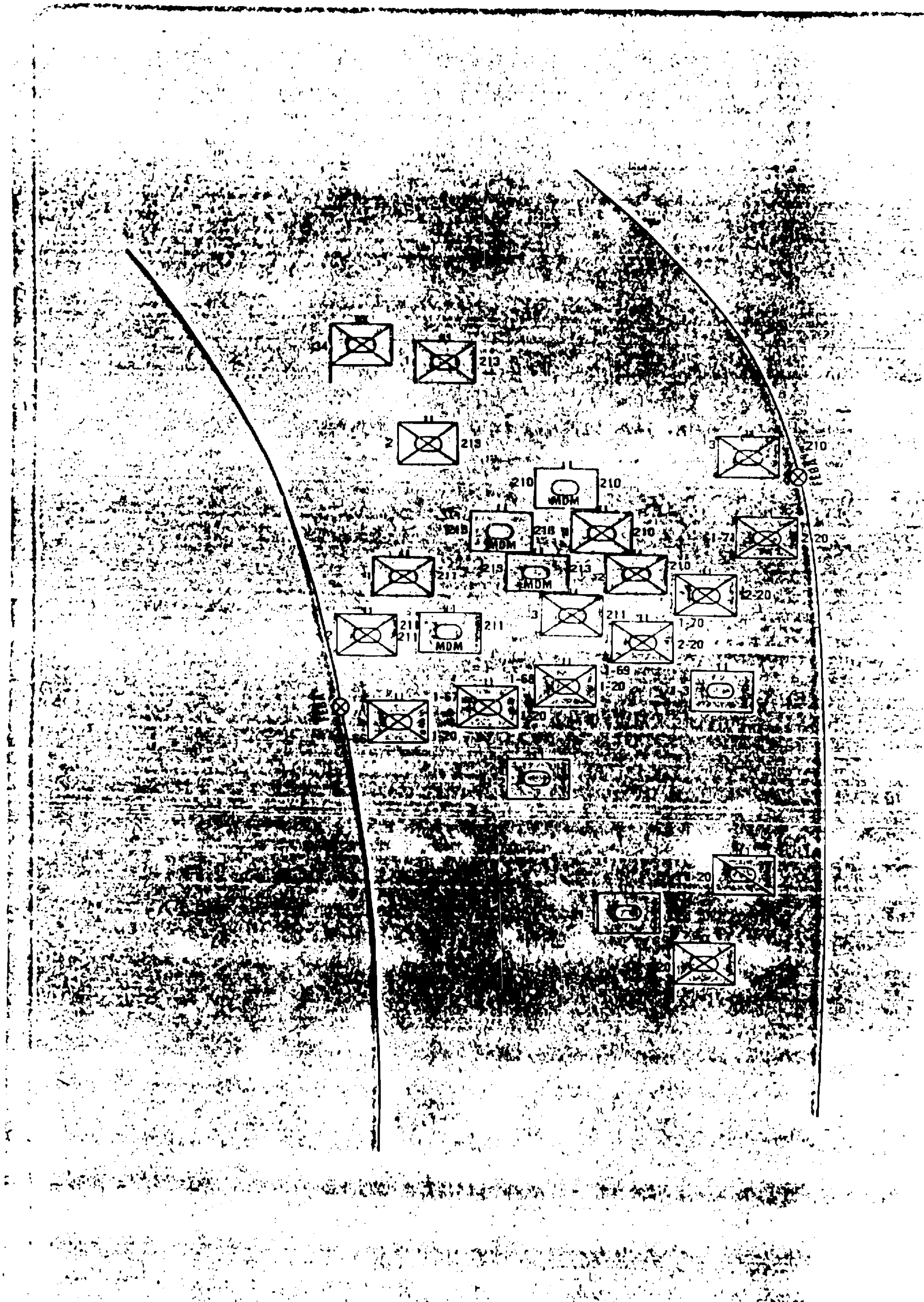

(SEMI-STRUCTURED)

5

FINAL REPORT

SELECTING AND REPRESENTING INFORMATION STRUCTURES FOR BATTLEFIELD DECISION SYSTEMS

By

Albert N. Badre

Prepared for

THE U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

September 19, 1977 to June 19, 1978

Grant No.: DAHC19—77—G—0022

June 11, 1977

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF INFORMATION AND COMPUTER SCIENCE
ATLANTA, GEORGIA 30332

SELECTING AND REPRESENTING INFORMATION STRUCTURES FOR BATTLEFIELD DECISION SYSTEMS

FINAL REPORT

Albert N. Badre

For

The U.S. Army Research Institute
for the Behavioral and Social Sciences

September 19, 1977 to June 19, 1978

Grant No.: DAHC19-77-G-0022

School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia

June 11, 1977

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Albert N. Badre
Principal Investigator
Georgia Institute of Technology

INTRODUCTION

Current decision-aiding and information processing systems have the impressive capabilities to capture, store, and use vast amounts of information (e.g., Colas, 1975). The design however of "intelligent" decision-aiding systems such that they are effectively compatible with the user's information processing needs requires a thorough understanding of how the decision-maker processes information. In general, a decision-maker is said to process information in a problem situation when he engages in functions such as channeling, storing, retrieving, and evaluating information in order to use it.

But as a prerequisite to a more complete specification of how the information is processed and used effectively, it is necessary to know how the problem data is represented and aggregated into meaningful informational structures. Research in artificial intelligence and information processing psychology strongly suggests that the way the problem data is represented has a direct bearing on the effectiveness with which it is used to select efficient solution procedures (Amarel, 1971; Newell & Simon, 1972; Badre, 1974).

BACKGROUND

Locating and Valuating Data Patterns. Generally, it may be assumed that there is a direct relationship between the competence of a problem solver, his representation of the given problem data, and, due to his representation, the heuristic procedure that he selects to solve the problem. The heuristics that he selects consist in part of the procedure he uses to define his evaluation function. The particular procedure that he chooses in turn is dependent on the specific information he uses to assign values to problem state descriptors. It may be further assumed that the more competent problem solvers tend to select, organize, and evaluate the data of a problem in specialized ways that lead them to select better heuristics for a given class of problems than the less competent ones. Accordingly, in order to develop effective decision-aiding heuristic programs, it is necessary to select user-compatible evaluation functions. The selection of such evaluation functions requires the identification of information structures, data patterns, or state descriptors which contain or constitute the parameters likely to be considered by the decision-maker in valuating his alternative problem states.

In order to prescribe how a user-compatible decision-aiding program should select pertinent data patterns for use by the decision-maker, it is necessary to identify the data patterns that are meaningful to that decision-maker. In fact, it is not sufficient to specify how in general decision-makers aggregate and represent task information. Rather, in order to write algorithms that are relatively effective in locating pertinent data patterns and organizing them into manageable data frames, it is necessary to determine what are the pertinent informational structures and state parameters that decision-makers of different levels of skill and experience are likely to process. This in turn requires a specification of the primitive data elements and how they may be combined to form potential relationships and meaningful patterns.

Decision-Aiding in Ill-Defined Problem Situations. Computer programs have been developed to aid or model the human decision-maker in various problem solving tasks. For example, Zobrist and Carlson (1973) describe an advice-taking program for chess. In the advice-taking portion of the program, the system's main function is to scan a board postion, then recognize and list the various "important" relations and patterns among pieces. Other systems have been developed to aid the organic chemist in analyzing mass spectrograms and to support the clinician in diagnosis and therapy (Buchanan, Sutherland, and Feigenbaum, 1969; Davis, Buchanan, and Shortliffe, 1977). Slamecka, Camp, Badre, and Hall (1977) have developed a pilot system that aids the clinician in his information gathering and aggregate data analysis tasks.

The levels of success and usefulness of various decision systems seem to vary as a function of the type and complexity of the problem for which they are designed (Donovan, 1976). While many of the artificial intelligence decision systems for well-defined problems have led to some useful applications, the success of other systems developed for ill-defined and dynamic problems has been limited.

Ill-defined problems are those where either: (a) the problem-space is enormously large that an explicit structural representation of the problem, e.g., graph or tree, cannot be effectively constructed prior to specifying an optimal solution path, such as in chess; or (b) the statement of the problem is incomplete, such as in clinical medicine. Problem statements are considered complete when they contain (explicitly or implicitly) a complete description of the initial state, the set of goal states, and the set of operators for transforming initial to goal states.

The main drawback of programs developed to aid or model the decision-maker in ill-defined decision situations has been the lack of reliance of the programmer on empirical validation techniques in selecting state descriptors that are (1) decision-maker compatible, and (2) different as a function of the competence level of the decision-maker. Instead, reliance on intuitiveness may be seen in the development of many of the computer programs for games of tactics and strategy such as chess (Newborn, 1975; Frey, 1977). With a few exceptions such as Samuel's checkers' program (1967), most programs that were designed to assist or model the decision-maker in ill-defined tactical decision situations have been relatively unsuccessful in performing at expert levels. The reason is that the selection of successful tactics depends on how the evaluation function is generated, which is based on, among other factors, the material value. The material value is directly related to the selection and scoring of key data units such as patterns. The selection and scoring of these data units have usually depended on either the programmer's intuitiveness and ability or the unvalidated verbal reports of experts. It is therefore necessary to identify an empirically reliable and replicable methodology for isolating, describing, and weighting the data units which constitute the elements of a state descriptor for a given problem and a given level of skill.

Experimental Research on Chunking. The underlying thesis of the experimental research on chunking is that when problem solvers process information from a given problem scenario, they do so in terms of well-formed structures and chunks; the content and size of such chunks as well as their perceived interrelationships are directly related to the problem solver's level of expertise. The leading research questions stemming from the chunking conjecture have been: (a) what constitutes the contents of a chunk for a given problem scenario and a given class of problem solvers; and (b) what is a valid experimental technique for identifying the boundaries of chunks?

The significance of determing chunk contents may be illustrated by considering the development of chess programs to both assist and play chess. Here, the procedure for defining evaluation functions for board positions consists of assigning numerical values to various components of a position such as material, area control, and mobility. It is generally assumed that in defining the evaluation function for a board position, material value should be a primary factor; and in order to generate material scores, the program should rely on fixed values assigned to individual pieces. This particular procedure for generating material scores of a given position makes the assumption that when a player defines an evaluation function for a given board position, he relies heavily on the values of individual chess pieces. While this assumption is intuitively appealing, there is some indication from chess memory experiments that the competent player engages in chunking the individual pieces into recognizable patterns (Chase and Simon, 1973; DeGroot, 1966; Charness, 1976; Dirlan, 1972; Frey and Adesman, 1976). This possibility gives rise to the alternative assumption that the competent player generates material scores by assigning values to chess patterns or relations among pieces rather than to chess pieces.

In the last few years, it has become increasingly apparent that research had to be done on how information is chunked and represented as the basis for defining the evaluation functions. Chase and Simon (1973) and later Reitman (1976) developed various techniques for studying the informational chunking question. Their approach was to compare the characteristics of chunks formulated by experts with those formulated by novices. The results of this research seem to support the conjecture that the expert problem solver structures his data and chunks his information differently than does the novice. His chunking is different with respect to both chunk size and chunk content. This difference seems to diminish as the information in the problem scenario becomes less coherent. More generally, experimental results have shown that the contents of a chunk may be rule-governed. A chess player may for example use criteria that are either chess meaningful such as forks and pins, or geometrically and spatially based such as linearity and locality, or chessmen characterized classifications such as all Rooks and all Bishops. Chase and Simon's results seem to indicate that those among other rules are used by the player in defining relations or patterns. What is not clear is how do these various relations interact to constitute a recall or perceptual chunk. In addition, Bower (1972), Bower and Winzenz (1969), and Restle and Brown (1970), have shown that in general perceptual, learning, and recall chunks are rule-based.

In order to be able to determine the contents of a chunk, Chase and Simon (1973) developed an empirical technique to identify chunk boundaries. The subjects in their experiments are asked to reconstruct and copy chess positions after viewing them for a few seconds. In the reconstruction task an experimental run consists of a successive number of trials. In each trial the subject is first shown a diagram of a chess position. He is allowed to study the diagram for a prespecified amount of time after which it is removed and he is asked to reconstruct it. As the subject is reconstructing the position, the experimenter records both the order and time of placement. In the copying task the subject is given the same position diagram as in the reconstruction task as well as a blank diagram. He is asked to copy the position on the blank diagram as rapidly and as accurately as he can. Again the experimenter records time and order of piece placement as the subject is copying the position. Then the average inter-placement time (IPT) is computed based on the recorded data. The IPT is then used to partition the reconstructed positions into chunks. If two pieces are placed at or below the IPT, they belong to the same chunk; otherwise, they are members of two different chunks. Reitman's results on the game of GO (1976) show that the inter-placement times used by Chase and Simon for defining chunk boundaries seem to be reliable only for patterns that can be partitioned linearly and sequentially. However, in the case of nested chunks the inter-response time measure does not apply with consistency. While many questions remain unanswered, the techniques that were introduced provide a basis for further research on informational chunking in various decision problems. The battlefield situation is one such problem.

In summary, the results of studies on chess, GO, and other games of tactics and strategy, as well as the more general results of research on organizational factors in memory indicate three main points. First, the skilled problem solver is able to process larger amounts of problem data than does the novice even though there does not seem to be a difference between the two on memory capacity. This difference in recall is related to the amount of prior experience with the given problem domain. Second, the organization of visually presented information affects the ability to recall that information. Randomly organized information reduces the superior ability of the expert to the level of ability held by a novice. The lack of typical organization of information may suppress the expert's ability to chunk the presented information. Third, the number of chunks used in representing the problem data may decrease as the amount of experience of a person increases. While this conclusion seems to be true for general cognitive organization, it was not true of the Chase and Simon results. As a person gains experience the nature of the representation of information changes from many specific chunks to a few generic ones. The reduction in the number of chunks represented may facilitate the organization and recall of information.

OBJECTIVES

The overall objective of this study was to identify and consider experimental techniques for locating and valuating data patterns and informational chunks that are meaningful to the tactical decision-maker in tasks such as the analysis of battlefield map positions. This objective is motivated by the long range need to (1) identify for a given class of problem situations the informational characteristics that constitute the basis for generating effective evaluation functions, and (2) relate the designation of meaningful units of information to the design of user-compatible data modules and data-searching and combining algorithms for tactical decision systems. More specifically, the objectives were as follows:

1. To compare the performance of battlefield experts with that of novices on the accuracy of recalling both coherent and noncoherent battlefield map positions;

2. To identify and apply experimental techniques for locating and distinguishing between the informational chunks that are formulated by the battlefield decision maker;

3. To identify the likely basic units that constitute the semantic contents of formulated chunks for specific battlefield maps;

4. To determine the comparative sizes of the average chunks for novices and experts;

5. To determine the comparative chunking frequency of novices and experts for a given battlefield scenario;

6. To determine the effect on recall, chunk size, chunk unit, and chunking frequency of varying the length of time given for viewing, processing, and assimilating the information.

METHOD

Subjects. Twenty-four subjects were selected to participate in the experiment. They came from two main groups: Twelve subjects were selected from a pool of military officers at Fort Benning, Georgia. The other 12 subjects came from Georgia Tech students who have never been exposed to battlefield situations or war games. The Georgia Tech subjects were paid $2.50 per hour for participating in the experiment. In choosing these two extremes of the subject population, we were able to make comparisons between two categories that are sufficiently distant with regard to experience with the given task.

Materials and Apparatus. The materials used in the experiment consisted of 12 reduced battlefield map displays. The maps were selected on the basis of four categories of structuring. The first category contains three structured maps; ones that come out of real battlefield situations. The second category contains three maps that were semistructured in that while, in general, the situation is plausible, it is not likely to occur with frequency. The third category contains three unstructured maps; they are unstructured in that the occurrence of such situations is not possible on a real battlefield. The fourth category contains the same three maps as in the first category with the addition of the unit designators to each of the unit symbols. Map examples are provided in Appendix I. A slide projector was used to present the maps for viewing by the subjects. For the time recordings, a sound synchronizer with a cassette beeper (the Wollensack 255) was used. Rubber stamps of each of the nine battlefield unit symbols for both the red and blue colors were made available. The subjects used the rubber stamps when reconstructing and copying the battlefield map unit symbols (see Figure 1 for a complete listing of unit symbols). A digit-span test was used in order to test for differences in short-term memory capacity between subjects in the two groups. The digit-span test is an expanded version of the test that comes out of the Wechsler Adult Intelligence Scale .

Procedure. The same procedure applied to all 24 subjects. Each subject first was briefed on the overall objectives of the study (see Appendix II). Afterwards, the experimenter begins with the following instructions:

> This is an experiment in human information processing not a test of your ability. On the table before you is a packet of sheets with a diagram of a battlefield background outlined on each sheet. On the screen in front of you, you will be shown a slide of a battlefield situation map. After ten seconds of viewing, I will

> remove the slide and your task will then be to reconstruct battlefield positions as accurately as you can on the diagram in front of you, using the rubber stamps placed to your right and left. Each of the red and blue symbols on the slides has a corresponding red or blue stamp. To remove a symbol, merely put a slash through it. To replace a symbol, put a slash through it, and then place the appropriate symbol somewhere next to it. You may have as much time as you need to reconstruct the position. Do you have any questions.

One pre-test slide was used for practice. After the instruction and one practice trial, the subject viewed a slide for ten seconds after which he was given as much time as he needed to reconstruct the position. The order of presenting slides to the subject was counterbalanced. After the subject completed the task for all 12 slides, he underwent a second reconstruction task using the same 12 slides with the only difference being that he was allowed a viewing time of one minute. The second reconstruction task was followed by a one-minute rest period after which the subject underwent the copying task.

The procedure for the copying task began with the following instructions:

> In this task you will be given the same 12 slides. You are asked to copy the information from the diagram on the screen onto the sheet in front of you by placing symbols in the appropriate locations as accurately and

as rapidly as you can. This procedure will be repeated for each of four slides.

The digit-span test was administered following the completion of the copying task. At the completion of the experiment each subject was asked to complete a biographical information questionnaire (see Appendix III). The entire experiment took one hour per subject to complete.

RESULTS AND DISCUSSION

Data Collection. There were essentially two kinds of data that were collected for both the reconstruction and copying tasks. These were symbol placement times and order of symbol placements. In the first case, one of two experimenters recorded the times of the placement of a symbol on a blank diagram by pressing a time key on the sound synchronizer-cassette at the beginning of each symbol placement. This procedure went on until the subject discontinued to place the symbols. This same experimenter also kept time for the ten-seconds and one-minute presentations in the reconstruction tasks. For the copying task, in addition to recording the symbol placement times, the experimenter recorded the times for the beginning and end of a glance to the diagram from which the subject was copying. The second type of data collected was the order in which the symbols were placed on the blank diagrams. This data was collected by the second experimenter who stood behind the subject and recorded the ordinals by using a blank diagram and writing the ordinal number in the location corresponding to that used by the subject to stamp the symbol.

Accuracy of Recall. A symbol is considered to be placed accurately if all its three properties, value, color, and location, are preserved with respect to the originally presented scenario-map. Tables 1 and 2 show the percent accuracy of recall of both novices and experts for the ten seconds (Task I) and the one minute (Task II) viewing times on the four scenario conditions. Using a mixed design which is a mixture of simple randomized and treatment by subject designs (Lindquist, 1953), a two-way analysis of variance of subject group x type of scenario on Task I revealed significant main effects for subject groups with $F(3,66) = 36.278$, $P < .001$, for scenario types with $F(1,22) = 17.314$, $P < .001$, and for groups x scenario types interaction with $F(3,66) = 2.824$, $P < .05$. Significant main effects were also obtained on Task II for subject groups with $F(3,66) = 35.842$, $P < .001$, for scenario types with $F(1,22) = 5.965$, $P < .05$, and groups x scenario types interaction with $F(3,66) = 2.627$, $P < .05$. In spite of the fact that there was no significant difference on the digit span test scores (novices 7.9 digits and experts 7.1 digits), it is clear from Tables 1 and 2 that the experts' performance is superior to that of the novices on the unstructured scenarios of Tasks I and II as well as on the structured scenarios of Task I. However, the same is not true of the structured scenarios of Task II. This finding may be explained by the possibility that a one-minute exposure time permits the subject to encode and memorize the location of a greater number of symbols up to an asymptotic level on the structured scenarios. However, the reason that performance differential becomes significant on the unstructured scenarios is that when the structured scenario is

Table 1

Percent of Symbol Placement Accuracy for Experts

Structure Type	Ten Seconds Task	One Minute Task
Structured	45.25	68.75
Structured with unit designator	47.34	75.69
Semi-Structured	36.84	70.33
Unstructured	22.69	40.63

Table 2

Percent of Symbol Placement Accuracy for Novices

Structure Type	Ten Seconds Task	One Minute Task
Structured	26.66	62.15
Structured with unit designator	30.90	69.79
Semi-Structured	26.07	44.33
Unstructured	15.62	24.65

destroyed, many of the non-tactical information structures that were available to the novice as mnemonic aids were also destroyed. There are many information structures that can be encoded and used as mnemonics by a subject who knows nothing about tactical operations. For example, all symbols of the same color and the same type that are placed adjacent to each other in a formation may be encoded quite easily as one chunk of information. Even though such a chunk may contain or constitute a tactical relation (see Table 3 for a complete list of tactical relations used in this experiment), a novice to the battlefield situation need not know the tactical components of such a chunk in order to use it in recalling a group of symbols. Accordingly, when such non-battlefield meaningful chunks were no longer available in the unstructured scenarios, the novices exhibited significantly lower performances than did the experts on the unstructured scenarios thus accounting for the interaction effects. The experts' performance did not drop as low as did the novices' between structured and unstructured scenarios on the second task because the unstructured scenarios still contained a fair number of battlefield meaningful relations (an average of 100 relations for unstructured scenarios compared with 300 for structured ones) which the expert could use for chunking.

Chunking Frequency. Two entirely different criteria were used to partition the reconstructed scenarios into chunks of symbols and relations between symbols. These were the inter-placement times criterion (IPT) and the sequence of tactically related symbols criterion (sequential). In order to compute the IPT, several assumptions were made. First, in the copying task, it was assumed that successive glances to the slide from which symbols are being copied define the boundary of chunks. That is, the symbols that were placed on the response diagram between two glances to the slide are referred to as the within-glance symbols and considered to constitute a chunk. Second, the average IPT was computed for the within-glance symbols of each subject and used to define the chunk boundaries in the reconstruction task. Symbols placed successively at or below the computed IPT were assumed to belong to the same chunk; those falling above the computed IPT were considered to come from two different chunks, hence defining a chunk-boundary in the reconstruction task. The IPT was computed for this experiment at exactly one second.

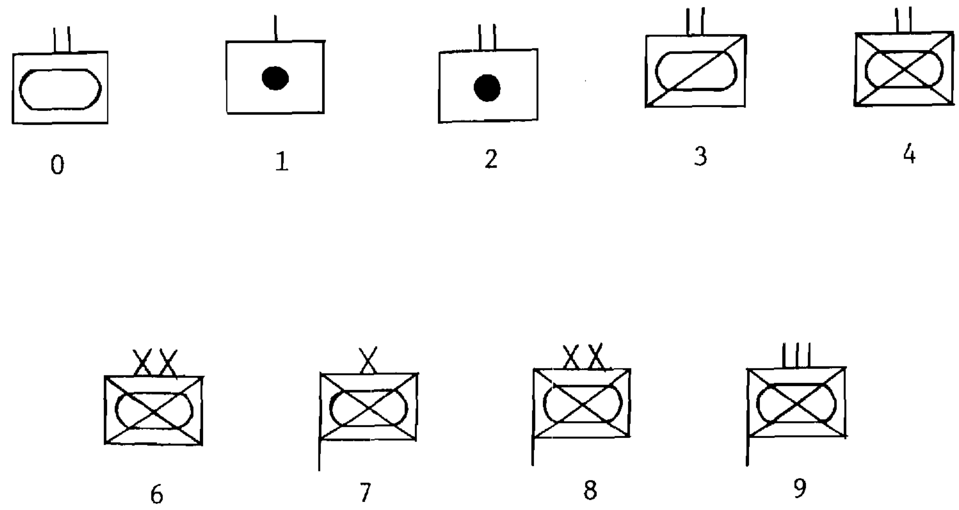
The sequential criterion for chunking used the predetermined battlefield relations (see Table 3) to partition the successively placed symbols of the reconstructed scenarios into chunks. A sequence of successively reconstructed symbols constitutes a chunk, if each symbol in the sequence, except the first one, is related to at least one other previously placed symbol in the same sequence. Once a symbol is found that is not related to any of the previously placed symbols in the sequence, then a discontinuity in the relatedness of the sequence occurs, defining the boundary of a chunk and making the interrupting symbol the first in a new chunk. The rationale for devising the sequential definition of chunking is to give an alternative to the IPT time constraint. The conjecture is that time may be an artificial constraint that is not a major factor in the expert's chunking behavior. But rather a meaningful development of the scenario by the expert is much more likely to be associated with the careful reconstruction of tactical semantics in the battlefield situation irrespective of time. A Pearson correlation test revealed no significant correlation between the IPT and sequential chunks on size, type of relation, or type of piece contained in a chunk. Evidently the two criteria for chunking represent two entirely different definitions of a chunk.

The reconstructed scenarios of both novices and experts were segmented into chunks using both the IPT and sequential criteria for chunking on the ten seconds and one minute tasks. The hypothesis being explored here is that the number of chunks per scenario condition will remain constant at about the short term capacity, 7 ± 2, on the ten seconds task irrespective of the structuredness of the scenario for both groups. However, with the opportunity to rehearse the information for a longer time period, the number of chunks per scenario will increase on the one minute task. A three-way analysis of variance on tasks, groups, and scenario types indicated a significant effect for tasks with $\underline{F}(1,211) = 42.684$, $P < .001$ for IPT chunks and with $\underline{F}(1,211) = 6.814$, $P < .01$ for sequential chunks. A significant scenario type effect was obtained with $\underline{F}(3,211) = 4.595$, $P < .005$ for IPT chunks and $\underline{F}(3,211) = 6.180$, $P < .005$ for sequential chunks. However, no significant effects were obtained for groups.

It is evident from inspecting the means that the average number of chunks per scenario remains constant at about five to eight chunks per group for the ten seconds task. The number of IPT chunks seems to increase for both groups on the one minute task by about two chunks over the ten seconds task. This finding suggests that availability of time to rehearse increases the number of recalled chunks. Unlike the findings of Chase and Simon (1973), these results show that the number of IPT chunks is not necessarily related to battlefield expertise. Rather, the number of chunks is related to the amount of time given for viewing the scenario irrespective of expertise.

Chunk Size. In order to determine the average size of a chunk, two different categories of chunk content were used: Symbols and relations. The chunk element that was more likely to be common and useful to both the novices and the experts was the individual symbol. There were a total of nine such symbols given in Figure 1. The tactical relation was used as a basic unit of chunk content and size in order to determine the extent to which experts chunk by relating symbols. Since the novice cannot chunk by battlefield meaningful relations, the relation-based chunk was used primarily to compare the expert's chunk size and content on the various scenarios for both IPT and sequential chunking over the ten seconds and one minute tasks. Table 3 gives a complete list of the battlefield relations used in the experiment. Figure 2 is an example of a complete set of relations for one of the structured scenarios.

A two way analysis of variance on symbols and relations per chunk for groups by scenario types revealed significant group effects with $\underline{F}(1,48) = 5.447$, $P < .05$ for IPT relations on the structured scenarios of the ten seconds task. Group effects were not significant for symbols on the ten seconds task. Similar effects were obtained for sequential relations and symbols on both tasks. Also a significant group effect was obtained for the IPT symbols of the one minute task



0 Armored Battalion
1 Artillery Battery
2 Artillery Battalion
3 Cavalry Squadron
4 Mechanized Battalion
6 Mechanized Division
7 Mechanized Brigade Headquarters
8 Mechanized Division Headquarters
9 Mechanized Regiment Headquarters

FIGURE 1. Unit Symbols Used in the Experiment

Table 3

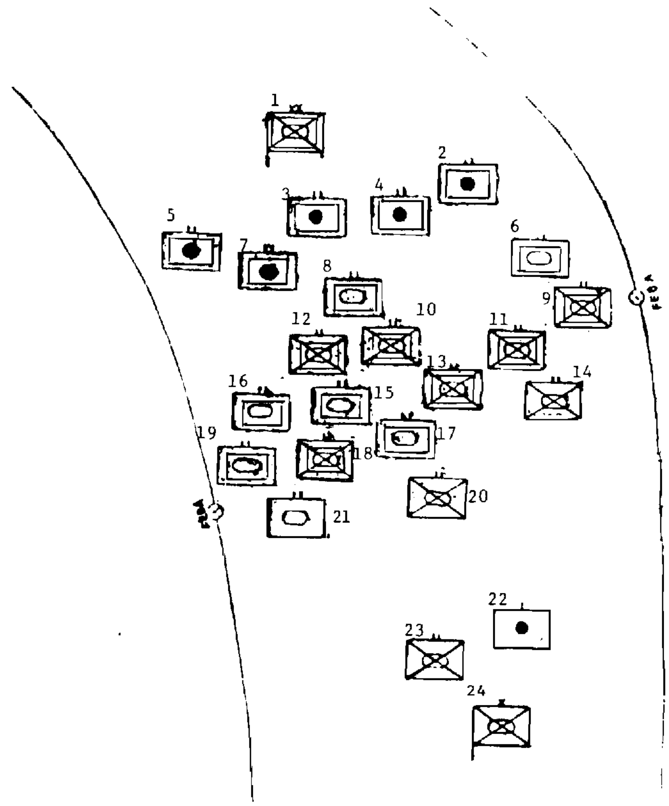
Battlefield Relations and Examples

	NAME	EXAMPLE*	SCENARIO
A	Front to Back	1 - 3	Structured
A2	Front to Front	13 - 11	Structured
B	Side to Side	2 - 4	Structured
B2	Lateral	9 - 11	Structured
C	Combat Support	3 - 9	Structured
D	Massing	16 - 19	Structured
E	Command	1 - 19	Structured
F	Face to Face	11 - 14	Structured
G	Counter Battery	3 - 22	Structured
H	Direct Support	3 - 14	Structured
I	Armored Cavalry near Headquarters	22 - 24	Structured - II

*The examples are given in the form n-m where n and m are the numbers of the related symbols in the indicated scenario found in Appendix I.

Double lines = Red

Single Line = Blue



1	2E,3AE,4E,5E,6E,7E,9CE,10E,11CE,12E,13CE,15E,16E,17CE,18CE,19CE
2	4B,9C,11C,13C,14H,17C,18C,19C,20H,21H,22G
3	2B,4B,9C,11C,13C,14H,17C,18C,19C,20H,21H,22G
4	2B,3B,9C,11C,13C,14H,17C,18C,19C,20H,21H,22G
5	3B,7B,9C,11C,13C,14H,17C,18C,19C,20H,21H,22G
6	9A,11A
7	3B,5B,9C,11C,13C,14H,17C,18C,19C,20H,21H,22G
8	10BD,12BD,13D,15D,16D,17D,18D,19D
9	11B2,14F
10	8D,12BD,13AD,15BD,16D,17AD,18D,19D
11	9B2,13B2,14F
12	8D,10BD,13D,15BD,16B2D,17D,18D,19D
13	8D,10D,11B2A2,12D,14F,15D,16D,17B2D,18D,19D
14	9F,11F,13F,20A2
15	8D,10D,12D,13AD,16BD,17AD,18AD,19D
16	8D,10D,12D,13D,15BD,17D,18AD,19AD
17	8D,10D,12D,13BD,15D,16D,18A2D,19D,20F
18	8D,10D,12D,13D,15D,16D,17A2D,19B2D,21F
19	8D,10D,12D,13D,15D,16D,17D,18B2D,21F
20	13F,14A2,17F,21A2
21	18F,19F,20A2
22	2G,3G,4G,5G,7G,9H,11H,13H,14C,17H,18H,19H,20C,21C,23B
23	22B
24	14CE,20CE,21CE,22AE,23AE

The symbol whose number is in the first column is in relation to the symbols following it by the relations indicated. For relation name see Table III.

Example: Piece 1 is related to Piece 2 by relation E; to Piece 3 by relations A and E, etc.

FIGURE 2. An Example of a Complete Set of Relations for a Structured Scenario

with $\underline{F}(1,10) = 15.885$, $P < .005$. Those results state that for the IPT ten seconds task and the sequential one minute task, while there were no significant differences in the number of symbols per chunk on the structured scenarios, significant differences were present for the number of relations per chunk. This finding suggests that in chunking, when given a structured battlefield scenario, for the same number of symbols, a greater number of relations exists between the expert's chunked symbols than between the same number of symbols of a novice's chunk. Evidently, experience leads to more relation-meaningful chunks. The significant effect on symbols and lack of it on relations for Task II is an exception to the above finding. It suggests that IPT chunking is not as sensitive to the relational content of chunks as is sequential chunking. On the other hand, when you consider that there are no significant differences on either symbols or relations per chunk for the unstructured scenarios of both tasks, under both criteria of chunking, it is clear that there is a direct relationship between the level of coherence of a scenario and the capacity of the decision maker to encode it and represent it meaningfully.

Tables 4, 5, 6, and 7 show the means and ranges for structured and unstructured scenarios of IPT and sequential chunking. It is evident from inspecting the means that the expert's sequential chunk size both in terms of relations and symbols is invariably larger for the structured than the unstructured scenarios. For IPT chunking, the exception is on the ten seconds task. Again, the consistency of the sequential results may be an indication that the sequential definition of chunking is more representative of the expert's chunking behavior.

Table 4

Averages and Range of Averages for the Number of Symbols Per IPT Chunk on the Structured and Unstructured Scenarios

	Ten Seconds Task		One Minute Task	
Scenario Type	Experts	Novices	Experts	Novices
Structured	2.09 (1-5)	1.66 (1.09-3.20)	2.86 (1.00-3.48)	1.42 (1.00-1.60)
Unstructured	2.70 (1.57-4.50)	3.27 (1.38-3.50)	1.40 (1.28-2.50)	1.46 (1.20-1.60)

Table 5

Averages and Range of Averages for the Number of Relations Per IPT Chunk on the Structured and Unstructured Scenarios

	Ten Seconds Task		One Minute Task	
Scenario Type	Experts	Novices	Experts	Novices
Structured	1.33 (0-5)	0.81 (0 -2.38)	0.62 (0 -2.00)	0.60 (0.31-1.50)
Unstructured	0.72 (0 -4.00)	0.45 (0 -7.50)	0.14 (0 -0.28)	0.13 (0 -0.31)

Table 6

Averages and Range of Averages for the Number of Symbols Per Sequential Chunk

Scenario Type	Ten Seconds Task		One Minute Task	
	Experts	Novices	Experts	Novices
Structured	2.88 (1.50-9.50)	1.73 (1.07-4.75)	5.00 (1.67-9.50)	5.48 (1.64-11.00)
Unstructured	1.50 (1.09-5.00)	2.27 (1.40-6.30)	1.88 (1.14-3.60)	1.60 (1.20-1.80)

Table 7

Averages and Range of Averages for the Number of Relations Per Sequential Chunk

Scenario Type	Ten Seconds Task		One Minute Task	
	Experts	Novices	Experts	Novices
Structured	5.78 (0.69-13.50)	4.48 (0.06-14.75)	3.01 (0-3.50)	1.92 (0.36-5.23)
Unstructured	1.30 (0-3.17)	1.41 (0-7.5)	1.00 (0-2.00)	0.98 (0.3.00)

In order to examine in greater depth the extent to which chunk size is related to expertise a breakdown of chunk size by the ordinal of the successively placed chunk was completed. Figures 3, 4, 5, and 6 compare novices with experts on chunk size as a function of chunk ordinal for IPT chunks. The sequential chunk results indicated similar trends. The figures show that chunk size is related to battlefield expertise only for the first few chunk ordinals. The experts seem to exhibit larger chunks on the first few ordinals of all scenarios for both tasks. The two groups are similar in that for both the chunk size is inversely related to chunk ordinal on the structured and unstructured scenarios of the ten seconds task. The curve for the one minute task is much less steep. The reason for this difference between the two tasks may be in part due to the greater amount of interference on the ten seconds task. Such interference effects have been repeatedly demonstrated in short-term memory research. Also, the one minute task may involve more problem solving which takes longer time and hence decreases and regulates the size of an IPT chunk. The curve steepness for the size of sequential chunks is greater than that of the IPT chunks for the one minute task.

Chunk Content. One of the main objectives of this study was to identify the most likely basic units that constitute the semantic contents of formulated chunks for specific battlefield maps. For a detailed understanding of the likely constituents of a chunk, both symbols and relations were examined by chunk ordinal. Tables 8 and 9 give summaries of types of symbols per IPT ordinal for both the ten seconds and one minute tasks on structured scenarios. Sequential and IPT chunks for types of symbols were fairly similar for structured

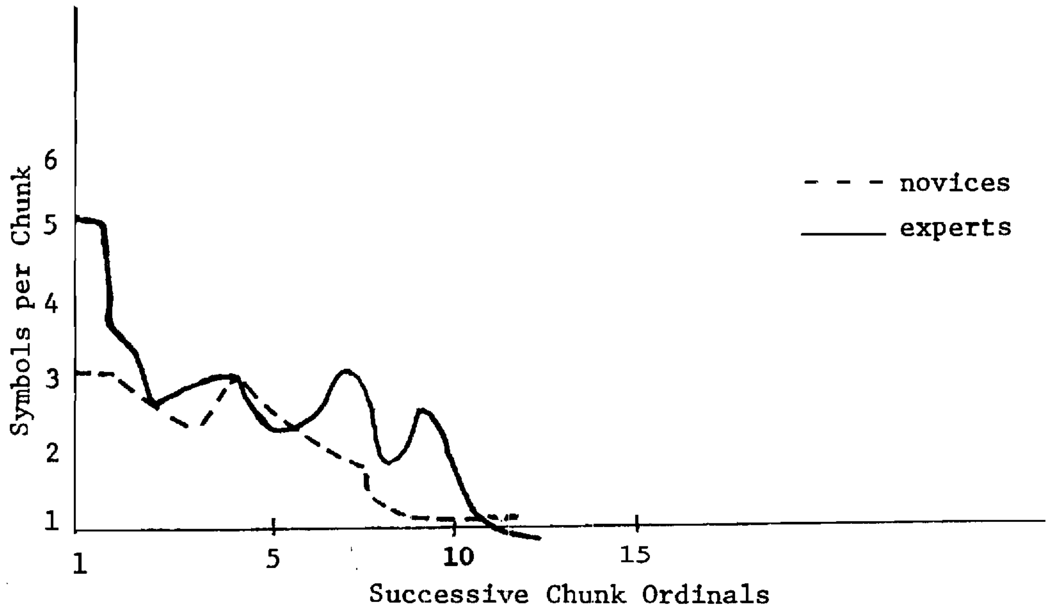


FIGURE 3. Chunk Size by Chunk Ordinal for Structured Scenarios of the Ten Seconds Task.

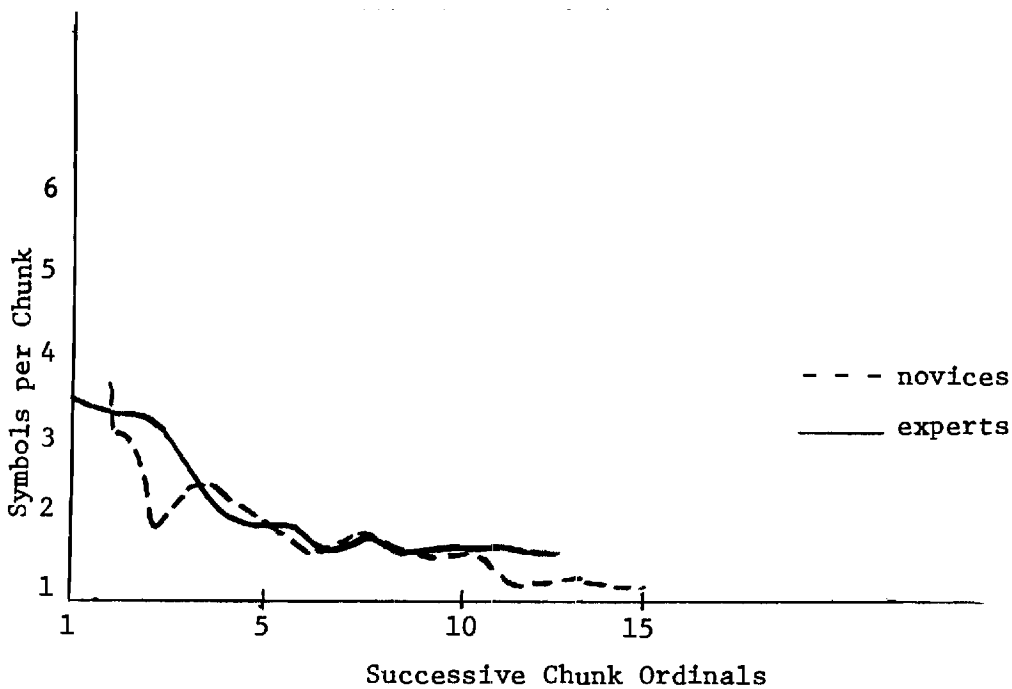


FIGURE 4. Chunk Size by Chunk Ordinal for Unstructured Scenarios of the Ten Seconds Task.

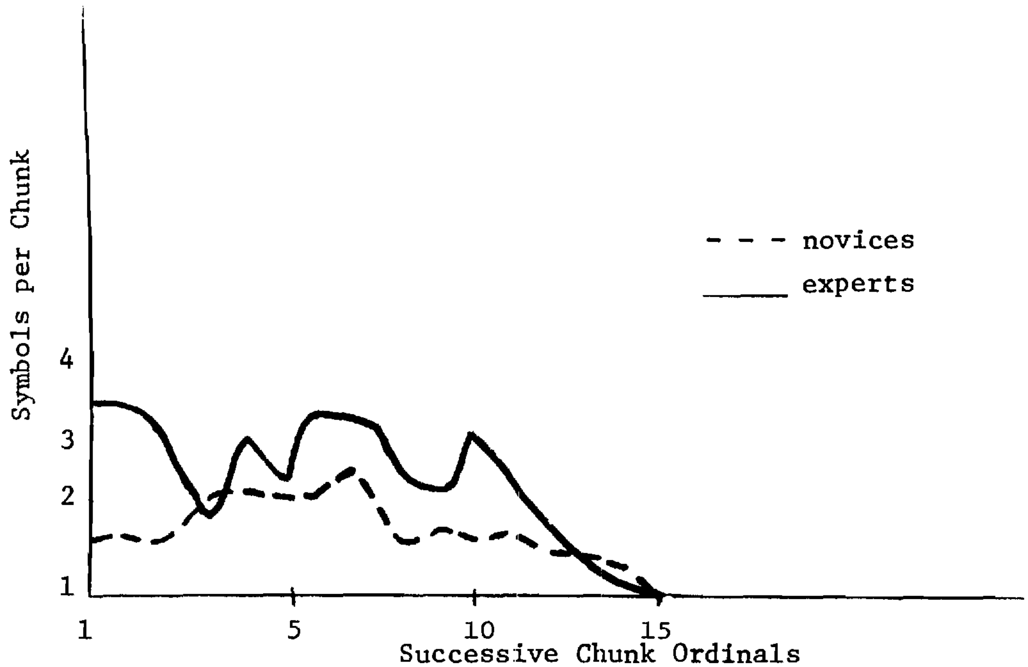


FIGURE 5. Chunk Size by Chunk Ordinal for Structured Scenario of the One Minute Task.

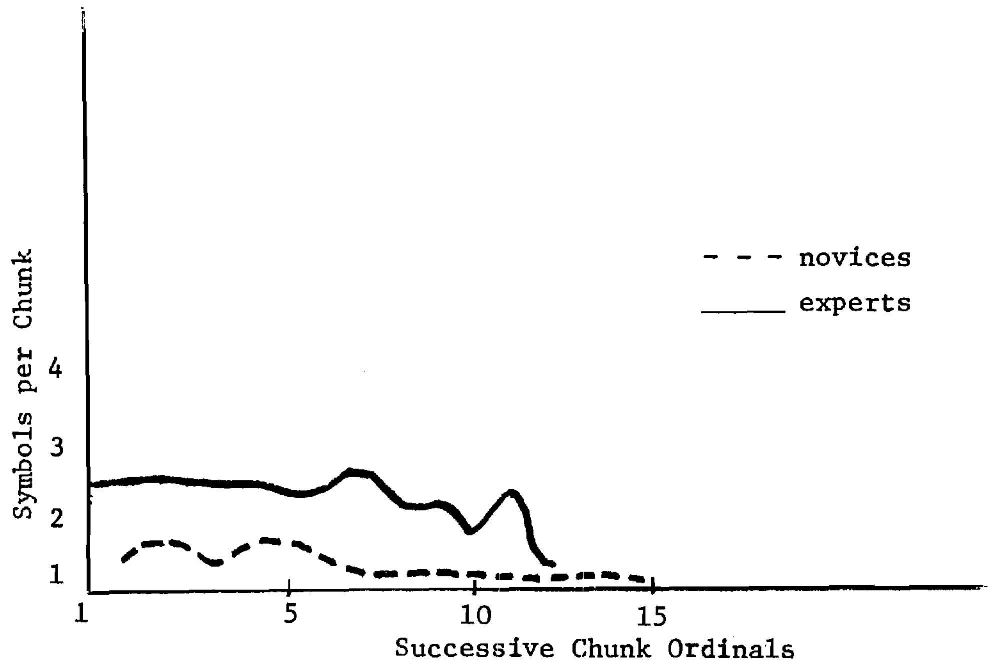


FIGURE 6. Chunk Size by Chunk Ordinal for Unstructured Scenarios of the One Minute Task.

Table 8

Summary of Types of Symbols by IPT Chunk Ordinal for Experts on Structured Scenarios of the Ten Seconds Task

Symbol Type*		Chunk Ordinals 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Red 0	COL	19.57	28.32	17.65	17.64	10.00	23.52	21.22	16.66	33.33	0.00	0.00	0.00	0.00	0.00
	ROW	19.15	19.15	12.77	12.77	4.26	8.51	14.89	4.26	4.26	0.00	0.00	0.00	0.00	0.00
Red 1	COL	4.35	7.41	0.00	0.00	0.00	0.00	0.00	0.00	16.66	25.00	50.00	33.33	0.00	0.00
	ROW	25.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50	12.50	12.50	12.50	0.00	0.00
Red 2	COL	17.39	17.51	3.61	2.93	5.00	0.00	18.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	36.36	22.73	4.55	4.55	4.55	0.00	27.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 3	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 4	COL	19.07	17.51	18.10	50.00	75.00	52.94	33.33	41.66	33.33	25.00	0.00	0.00	0.00	0.00
	ROW	11.39	6.33	6.33	21.52	18.99	11.39	13.92	6.33	2.53	1.27	0.00	0.00	0.00	0.00
Red 6	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 7	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 8	COL	0.00	0.00	14.49	0.00	0.00	0.00	3.02	8.33	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	66.67	0.00	0.00	0.00	16.67	16.67	0.00	0.00	0.00	0.00	0.00	0.00
Red 9	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 0	COL	2.16	4.20	3.61	2.93	0.00	0.00	6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	16.67	16.67	16.67	16.67	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 1	COL	2.16	7.41	0.00	2.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.00	100.00
	ROW	16.67	33.33	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	16.67
Blue 2	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 3	COL	2.16	0.00	3.61	2.93	0.00	0.00	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	25.00	0.00	25.00	25.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 4	COL	28.27	17.68	25.34	14.71	0.00	17.65	12.13	33.33	16.66	50.00	50.00	33.33	100.00	0.00
	ROW	27.66	10.64	14.89	10.64	0.00	6.38	8.51	8.51	2.13	4.26	2.13	2.13	2.13	0.00
Blue 6	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 7	COL	4.36	0.00	0.00	5.89	10.00	5.89	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	25.00	0.00	0.00	25.00	25.00	12.50	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 8	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 9	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of symbol see Figure 1.

Col. value = The percent frequency of the symbols that were placed on the given ordinal were of the type named.

Row value = Of all the symbols of the given type that were placed, the row value represents the percent placed on the given ordinal.

Table 9

Summary of Types of Symbols by IPT Chunk Ordinal for Experts on Structured Scenarios of the One Minute Task

Symbol Type *		Chunk Ordinals 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Red 0	COL	0.00	23.00	28.57	46.15	50.00	15.38	42.85	42.85	11.11	0.00	16.66	0.00	0.00	0.00
	ROW	0.00	10.71	7.14	21.43	14.29	7.14	21.43	10.71	3.57	0.00	3.57	0.00	0.00	0.00
Red 1	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 2	COL	0.00	0.00	0.00	15.38	25.00	38.46	0.00	28.57	55.55	40.00	33.33	25.00	0.00	0.00
	ROW	0.00	0.00	0.00	8.70	8.70	21.74	0.00	8.70	21.74	17.39	8.70	4.35	0.00	0.00
Red 3	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 4	COL	28.38	23.08	14.29	30.77	25.00	38.46	42.85	14.28	0.00	40.00	0.00	0.00	0.00	0.00
	ROW	13.33	10.00	3.33	13.33	6.67	16.67	20.00	3.33	0.00	13.33	0.00	0.00	0.00	0.00
Red 6	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 7	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red 8	COL	0.00	0.00	14.29	0.00	0.00	7.69	0.00	0.00	11.11	10.00	0.00	50.00	0.00	0.00
	ROW	0.00	0.00	16.67	0.00	0.00	16.67	0.00	0.00	16.67	16.67	0.00	33.33	0.00	0.00
Red 9	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 0	COL	7.10	15.39	14.29	0.00	0.00	0.00	7.19	0.00	11.11	0.00	0.00	0.00	50.00	50.00
	ROW	12.50	25.00	12.50	0.00	0.00	0.00	12.50	0.00	12.50	0.00	0.00	0.00	12.50	12.50
Blue 1	COL	14.19	0.00	0.00	7.70	0.00	0.00	0.00	0.00	11.11	0.00	16.67	25.00	0.00	0.00
	ROW	33.33	0.00	0.00	16.67	0.00	0.00	0.00	0.00	16.67	0.00	16.67	16.67	0.00	0.00
Blue 2	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 3	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 4	COL	42.58	38.45	14.29	0.00	0.00	0.00	7.19	14.28	0.00	10.00	0.00	0.00	0.00	50.00
	ROW	37.50	31.25	6.25	0.00	0.00	0.00	6.25	6.25	0.00	6.25	0.00	0.00	0.00	6.25
Blue 6	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 7	COL	7.10	0.00	14.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.00	50.00	0.00
	ROW	20.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	20.00	0.00
Blue 8	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue 9	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of symbol see Figure 1.

Col. value = The percent frequency of the symbols that were placed on the given ordinal were of the type named.

Row value = Of all the symbols of the given type that were placed, the row value represents the percent placed on the given ordinal.

scenarios. Since the chunk content results may lead to actual display and presentation applications, it was considered that structured scenarios would be the only useful ones for those results. Tables 10, 11, 12, and 13 give summaries of relation type frequencies by chunk ordinal. For any given entry in all of the tables, a column value represents the percent frequency with which the named type of symbol is present as part of the reconstructed symbols on that ordinal. The row value represents the percent frequency associated with that ordinal for all symbols of the named type that were placed on the reconstructed scenario. The same row and column definitions apply to the relation types. For example, on Table 10, consider the front to back relation of chunk ordinal 1. The values read as follows: Col = 6.61% of the relations that were placed on the first ordinal were front to back type relations; Row = of all front to back relations placed, 40% of them were placed on the first ordinal.

Relation Latencies. A major theme of this study is that there is a direct relationship between the speed and ease with which information is assimilated and represented and the coherence of the presented information. Likewise the coherence with which the subject views and organizes his information is likely to be reflected in the speed with which he processes the information. In order to examine the conjecture that speed of processing is related to the coherence with which information is organized and represented by the subject, it was assumed that a chunk with a greater number of relations is more coherently organized than one with less number of relations. Accordingly, the number of relations for a chunk should be inversely proportional to the average IPT for a chunk. Figures 7, 8, 9, and 10 show that in general

Table 10

Summary of Types of Relations by IPT Chunk Ordinal for Experts on Structured Scenarios of the Ten Seconds Task

Relation Type*		Chunk Ordinals 1	2	3	4	5	6	7	8	9
A	COL	7.32	0.00	7.14	0.00	0.00	0.00	4.92	0.00	0.00
	ROW	42.86	0.00	14.29	0.00	0.00	0.00	42.86	0.00	0.00
A2	COL	14.63	0.00	14.29	14.29	10.00	0.00	1.64	0.00	0.00
	ROW	40.00	0.00	13.33	33.33	6.67	0.00	6.67	0.00	0.00
B	COL	14.63	50.00	7.14	0.00	10.00	0.00	11.48	0.00	0.00
	ROW	30.00	25.00	5.00	0.00	5.00	0.00	35.00	0.00	0.00
B2	COL	14.63	10.00	7.14	17.14	30.00	20.00	8.20	100.00	0.00
	ROW	24.00	4.00	4.00	24.00	12.00	8.00	20.00	4.00	0.00
C	COL	0.00	0.00	14.29	11.43	0.00	20.00	32.79	0.00	0.00
	ROW	0.00	0.00	7.14	14.29	0.00	7.14	71.43	0.00	0.00
D	COL	4.88	40.00	35.71	34.29	50.00	50.00	21.31	0.00	0.00
	ROW	4.35	8.70	10.87	26.09	10.87	10.87	28.26	0.00	0.00
E	COL	0.00	0.00	7.14	8.57	0.00	10.00	16.39	0.00	0.00
	ROW	0.00	0.00	6.67	20.00	0.00	6.67	66.67	0.00	0.00
F	COL	9.76	0.00	0.00	5.71	0.00	0.00	1.64	0.00	0.00
	ROW	57.14	0.00	0.00	28.57	0.00	0.00	14.29	0.00	0.00
G	COL	9.76	0.00	7.14	8.57	0.00	0.00	1.64	0.00	0.00
	ROW	44.44	0.00	11.11	33.33	0.00	0.00	11.11	0.00	0.00
H	COL	21.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	COL	2.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of relation see Table 3.

Col. value = The percent frequency of the relations that were placed on the given ordinal were of the type named.

Row value = Of all the relations of the given type that were placed, the row value represents the percent placed on the given ordinal.

Table 11

Summary of Types of Relations by IPT Chunk Ordinal for Experts on Structured Scenarios of the One Minute Task

Relation Type*		Chunk Ordinals 1	2	3	4	5	6	7	8	9	10	11	12	13
A	COL	0.00	0.00	0.00	0.00	0.00	0.00	23.08	0.00	0.00	0.00	16.67	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	75.00	0.00	0.00	0.00	25.00	0.00	0.00
A2	COL	33.33	28.57	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	40.00	40.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	COL	33.33	0.00	0.00	0.00	25.00	16.67	7.69	0.00	100.00	33.33	16.67	0.00	0.00
	ROW	20.00	0.00	0.00	0.00	10.00	20.00	10.00	0.00	20.00	10.00	10.00	0.00	0.00
B2	COL	33.33	28.57	0.00	20.00	25.00	0.00	15.38	0.00	0.00	66.67	0.00	0.00	0.00
	ROW	20.00	20.00	0.00	10.00	10.00	0.00	20.00	0.00	0.00	20.00	0.00	0.00	0.00
C	COL	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	COL	0.00	28.57	0.00	60.00	50.00	25.00	53.85	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	11.76	0.00	17.65	11.76	17.65	41.18	0.00	0.00	0.00	0.00	0.00	0.00
E	COL	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00	16.67	100.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	25.00	50.00	0.00
F	COL	0.00	14.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
H	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
I	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of relation see Table 3.

Col. value = The percent frequency of the relations that were placed on the given ordinal were of the type named.

Row value = Of all the relations of the given type that were placed, the row value represents the percent placed on the given ordinal.

Table 12

Summary of Types of Relations by Sequential Chunk Ordinals for Experts on Structured Scenarios of the Ten Seconds Task

Relation Type*		Chunk Ordinals										
		1	2	3	4	5	6	7	8	9	10	11
A	COL	6.98	8.61	6.67	11.36	0.00	0.00	3.33	0.00	0.00	0.00	0.00
	ROW	19.35	41.94	19.35	16.13	0.00	0.00	3.23	0.00	0.00	0.00	0.00
A2	COL	6.98	1.99	5.56	4.55	1.33	10.53	6.67	12.50	50.00	0.00	0.00
	ROW	26.09	13.04	21.74	8.70	4.35	8.70	8.70	4.35	4.35	0.00	0.00
B	COL	11.63	11.92	13.33	6.82	6.67	5.26	3.33	0.00	50.00	0.00	0.00
	ROW	19.61	35.29	23.53	5.88	9.80	1.96	1.96	0.00	1.96	0.00	0.00
B2	COL	16.28	5.30	5.56	15.91	9.33	36.84	0.00	25.00	0.00	0.00	0.00
	ROW	28.00	16.00	10.00	14.00	14.00	14.00	0.00	4.00	0.00	0.00	0.00
C	COL	22.09	25.17	11.11	2.27	40.00	0.00	33.33	12.50	0.00	0.00	0.00
	ROW	17.43	34.86	9.17	0.92	27.52	0.00	9.17	0.92	0.00	0.00	0.00
D	COL	25.58	28.48	27.78	54.55	17.33	36.84	3.33	37.50	0.00	0.00	100.00
	ROW	15.83	30.94	17.99	17.27	9.35	5.04	0.72	2.16	0.00	0.00	0.72
E	COL	4.65	13.25	15.56	0.00	6.67	0.00	23.33	12.50	0.00	0.00	0.00
	ROW	7.84	39.22	27.45	0.00	9.80	0.00	13.73	1.96	0.00	0.00	0.00
F	COL	4.65	3.97	0.00	2.27	6.67	10.53	6.67	0.00	0.00	0.00	0.00
	ROW	20.00	30.00	0.00	5.00	25.00	10.00	10.00	0.00	0.00	0.00	0.00
G	COL	0.00	1.32	1.11	0.00	1.33	0.00	6.67	0.00	0.00	0.00	0.00
	ROW	0.00	33.33	16.67	0.00	16.67	0.00	33.33	0.00	0.00	0.00	0.00
H	COL	0.00	0.00	13.33	0.00	10.67	0.00	13.33	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	50.00	0.00	33.33	0.00	16.67	0.00	0.00	0.00	0.00
I	COL	1.16	0.00	0.00	2.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	50.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of relation see Table 3.

Col. value = The percent frequency of the relations that were placed on the given ordinal were of the type named.

Row value = Of all the relations of the given type that were placed, the row value represents the percent placed on the given ordinal.

Table 13

Summary of Types of Relations by Sequential Chunk Ordinals for Experts on Structured Scenarios of the One Minute Task

Relation Type*		Chunk Ordinals											
		1	2	3	4	5	6	7	8	9	10	11	12
A	COL	6.61	10.00	7.50	0.00	7.69	0.00	5.26	13.04	0.00	0.00	0.00	16.67
	ROW	40.00	10.00	15.00	0.00	10.00	0.00	5.00	15.00	0.00	0.00	0.00	5.00
A2	COL	7.44	10.00	10.00	0.00	3.85	0.00	5.26	4.35	0.00	0.00	0.00	0.00
	ROW	50.00	11.11	22.22	0.00	5.56	0.00	5.56	5.56	0.00	0.00	0.00	0.00
B	COL	4.13	15.00	5.00	0.00	7.69	100.00	0.00	21.74	0.00	0.00	100.00	33.33
	ROW	22.73	13.64	9.09	0.00	9.09	9.09	0.00	22.73	0.00	0.00	4.55	9.09
B2	COL	5.76	10.00	5.00	0.00	15.38	0.00	21.05	0.00	0.00	0.00	0.00	0.00
	ROW	36.84	10.53	10.53	0.00	21.05	0.00	21.05	0.00	0.00	0.00	0.00	0.00
C	COL	29.75	0.00	37.50	0.00	3.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	69.23	0.00	28.85	0.00	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	COL	30.58	35.00	7.50	0.00	61.54	0.00	52.63	0.00	0.00	0.00	0.00	0.00
	ROW	50.68	9.59	4.11	0.00	21.92	0.00	13.70	0.00	0.00	0.00	0.00	0.00
E	COL	8.26	10.00	25.00	0.00	0.00	0.00	5.26	39.13	0.00	0.00	0.00	50.00
	ROW	28.57	5.71	28.57	0.00	0.00	0.00	2.86	25.71	0.00	0.00	0.00	8.57
F	COL	7.44	10.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	75.00	16.67	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	COL	0.00	0.00	0.00	0.00	0.00	0.00	5.26	21.74	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	16.67	83.33	0.00	0.00	0.00	0.00
H	COL	0.00	0.00	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
I	COL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For name of relation see Table 3.

Col. value = The percent frequency of the relations that were placed on the given ordinal were of the type named.

Row value = Of all the relations of the given type that were placed, the row value represents the percent placed on the given ordinal.

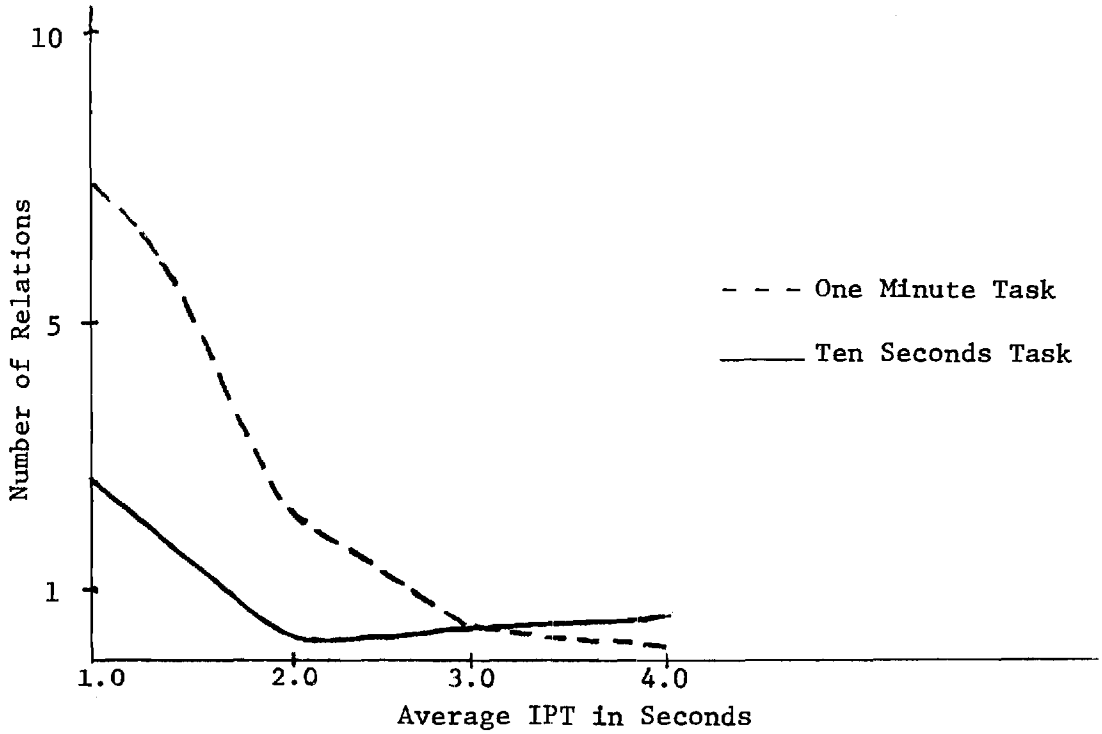


FIGURE 7. Number of Relations in an IPT Chunk by Average IPT for Chunk on Structured Scenarios for Experts.

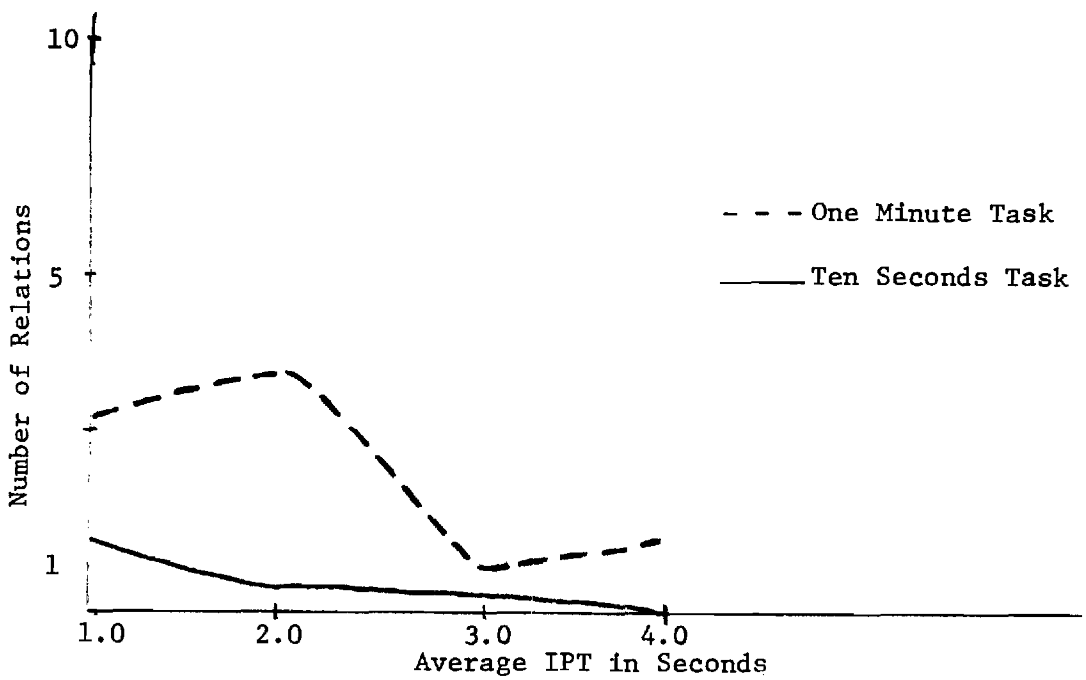


FIGURE 8. Number of Relations in an IPT Chunk by Average IPT for Chunk on Structured Scenarios for Novices.

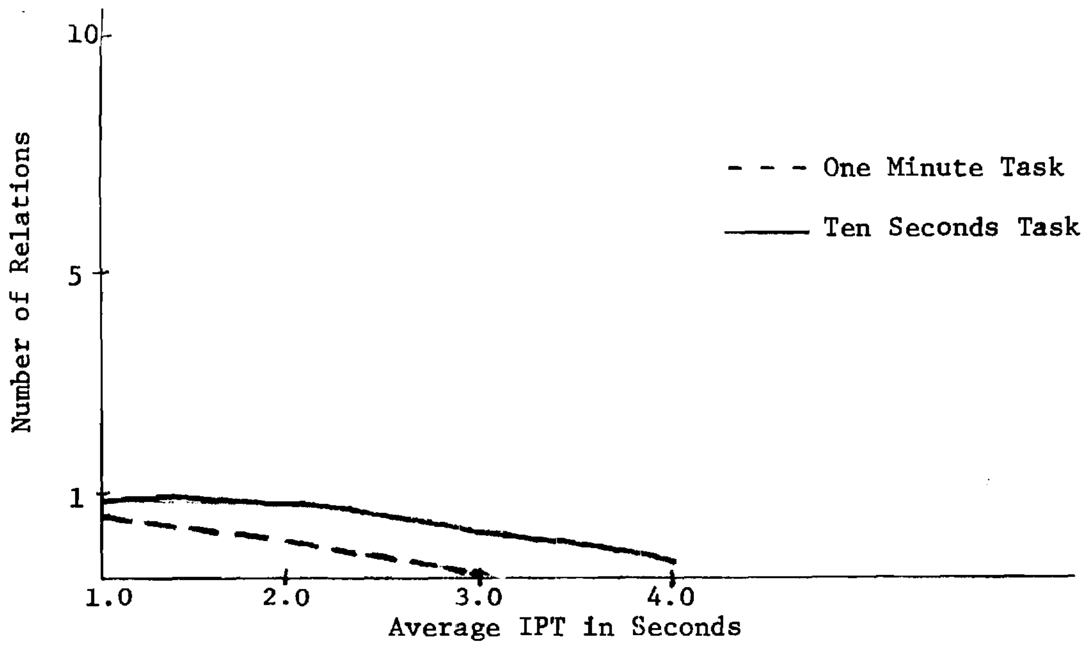


FIGURE 9. Number of Relations in an IPT Chunk by Average IPT for Chunk on Unstructured Scenarios for Experts.

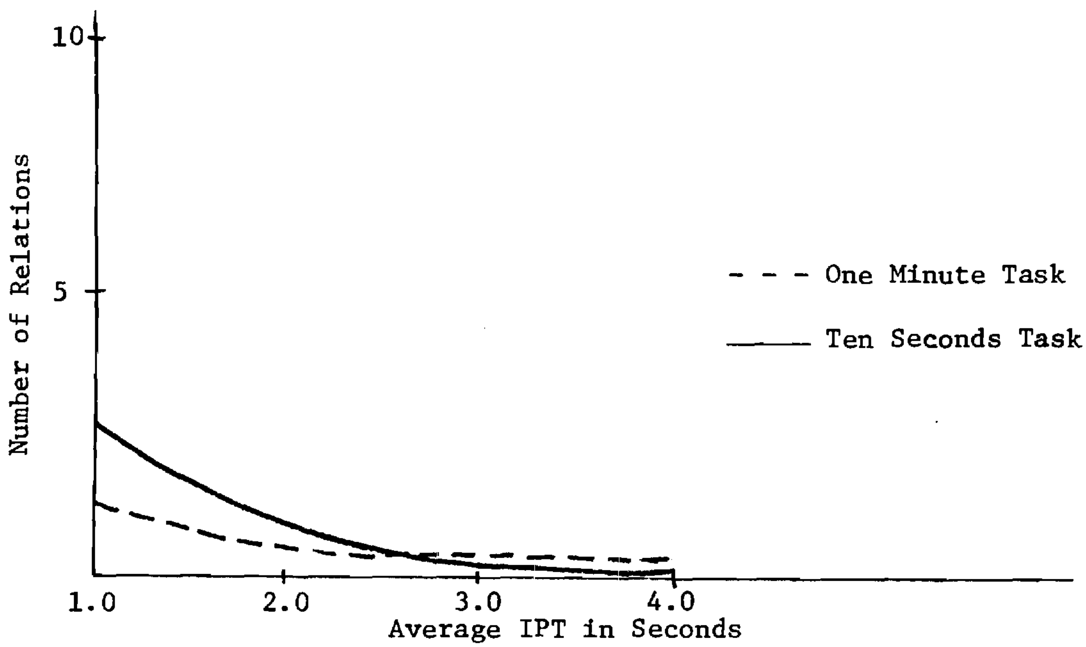


FIGURE 10. Number of Relations in an IPT Chunk by Average IPT for Chunk on Unstructured Scenarios for Novices.

as the number of relations goes up, processing inter-placement time goes down for both novices and experts on the structured scenarios. While this trend is still true for the unstructured scenarios, the variance between the two tasks is greater for the structured than for the unstructured scenarios. Also the difference between the two groups is greater for the structured than for the unstructured scenarios, suggesting that processing speed is dependent on both the coherence of the chunk and the coherence of the display. Thus both chunk coherence and display coherence may be measured by the relative number of relations each contains. The fact that novices exhibited similar trends is based on the possibility that they used relations between symbols which are coterminous with battlefield relations but not necessarily tactically meaningful.

CONCLUSIONS

The present study has provided an experimental technique by which to locate and valuate the informational chunks which are meaningful to the tactical decision maker in the analysis of battlefield map positions. Tactically meaningful relations tended to emerge as the basic elements of an expert's chunk. Even the novice was chunking by relating symbols in some meaningful way. One indication of this finding is that there seems to be a direct relationship between the relational density of a chunk and the speed with which the information is processed. While chunk size in terms of relations was related to battlefield expertise, no such relationship was found for chunking frequency. Chunking frequency was more directly related to time given for studying the battlefield map irrespective of expertise. Those findings need to be validated for varying display conditions and more dynamic battlefield scenarios.

Acknowledgements:

I wish to thank the following persons for their participation and helpful assistance on this research project: Ms. Elaine Acree and Mr. Timothy Cope of the Georgia Institute of Technology; Dr. Edgar Johnson, Dr. Stan Halpin, and CPT. David Candler of the Army Research Institute.

REFERENCES

Amarel, S. Representations and modeling of problems of program formation. In B. Meltzer and D. Michie (eds), Machine Intelligence, Edinburgh: Edinburgh University Press, 1971.

Badre, A. N. Information processing approaches to problem-solving, Research 1973/74: Annual Progress Report, School of Information & Computer Science, Georgia Tech, pp. 30-32, 1974.

Bower, Gordon H. A selective review of organizational factors in memory. In E. Tulving and W. Davidson (eds), Organization of Memory, New York, N.Y., Academic Press, 1972.

Bower, G. H. & Winzenz, D. Group structure, coding, and memory for digit series, Journal of Experimental Psychology Monographs, Vol. 80, No. 2, Part 2, pp. 1-17, 1969.

Buchanan, B. et al, Heuristic DENDRAL: A program for generating explanatory hypotheses in organic chemistry, Machine Intelligence 4, New York: American Elsevier, 1969.

Charness, Neil, Memory for chess positions: Resistance to interference, Journal of Experimental Psychology: Human Learning and Memory, Vol. 2, No. 6, 1976.

Chase, W. G. & Simon, H.A. The mind's eye in chess. In W. G. Chase (ed), Visual Information Processing, New York: Academic Press, 1973.

Colas, J. N. G-2 SIMTOS: A Research Vehicle for the Study of Tactical Intelligence Information Processing and Decision-Making, Vol. I & II Essex Corporation, July 1975.

Davis, R. et al. Production rules as a representation for a knowledge based consultation program, Artificial Intelligence, Vol. 8, 1977.

deGroot, A. Perception and memory versus thought: Some old ideas and recent findings. In B. Kleinmuntz (ed), Problem Solving, New York: Wiley, 1966.

Dirlan, David K. Most efficient chunk sizes, Cognitive Psychology, Vol. 3, 1972.

Donovan, J.J. Database system approach to management decision support, ACM Transactions on Decision Systems, Vol. 1, No. 4, December 1976.

Frey, Peter W. (ed) Chess Skill in Man and Machine, New York: Springer-Verlag, 1977.

Frey, Peter W. & Ademan, Peter Recall memory for visually presented chess positions, Memory and Cognition, Vol. 4, No. 5, 1976.

Lindquist, E. F. Design and Analysis of Experiments in Psychology and Education, Boston: Houghton Mifflin Co., pp. 266-273, 1953.

Newborn, M. Computer Chess, New York: Academic Press, 1975.

Newell, A. & Simon, H. A. Human Problem Solving, Englewood Cliffs, New Jersey: Prentice-Hall, 1972.

Reitman, J. S. Skilled perception in GO: Deducing memory structures from inter-response times, Cognitive Psychology, Vol. 8, No. 3, pp. 336-356, July 1976.

Restle, F. & Brown E. Organization of serial pattern learning. In G. H. Bower (ed), The Psychology of Learning and Motivation, Vol. 4, New York: Academic Press, 1970.

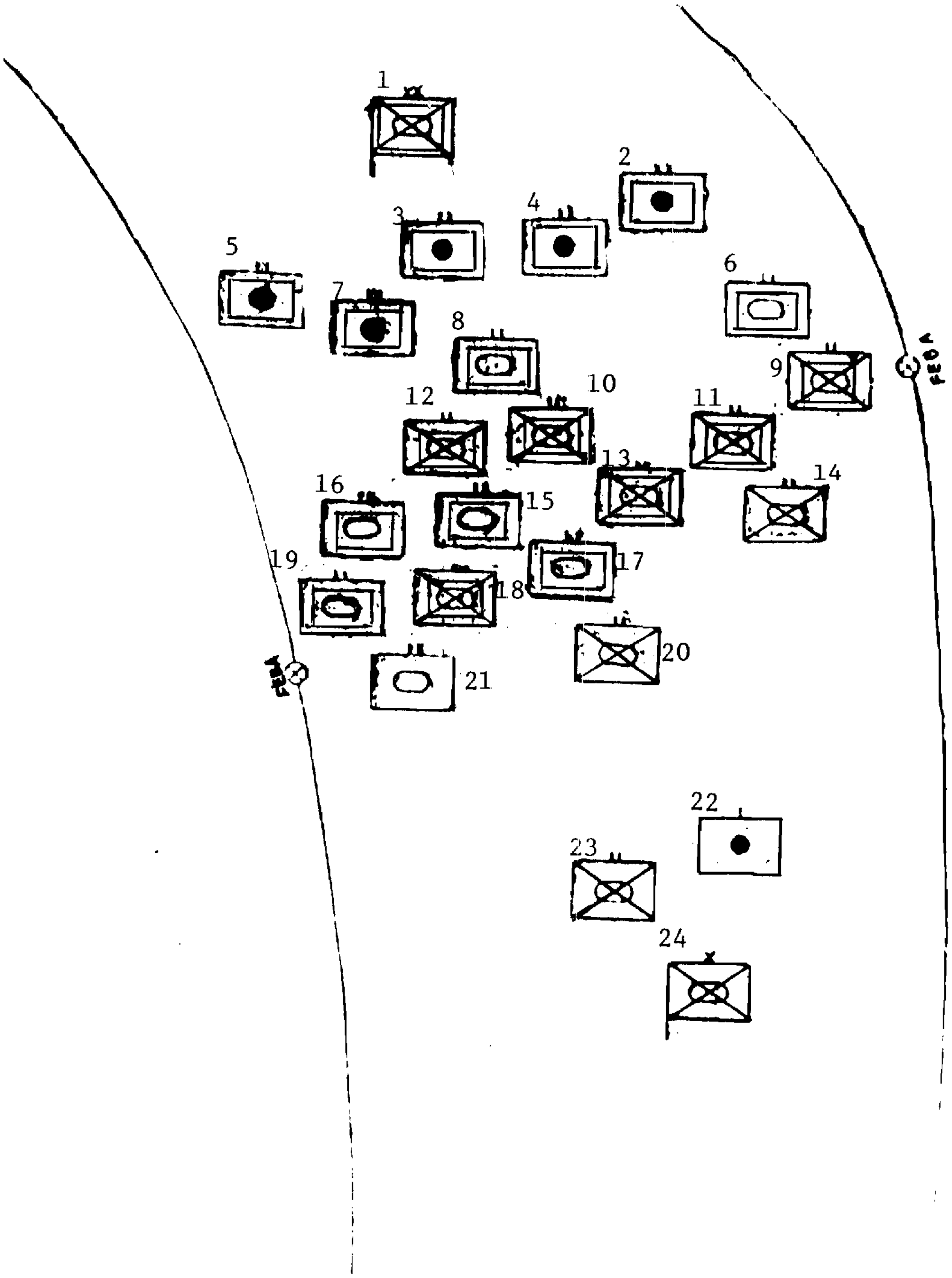
Samuel, A. L. Some studies in machine learning using the game of checkers II. Recent progress, IBM Journal of Research and Development, Vol. 11, No. 6, 1967.

Slamecka, V., Camp, H., Badre, A. N., and Hall, D. MARIS: A knowledge system for internal medicine, Journal of Information Management and Processing, Vol. 13, pp. 273-276, 1977.

Zobrist, A. L. & Carlson, F. R., Jr. An advice-taking chess computer, Scientific American, Vol. 228, pp. 92-105, 1973.

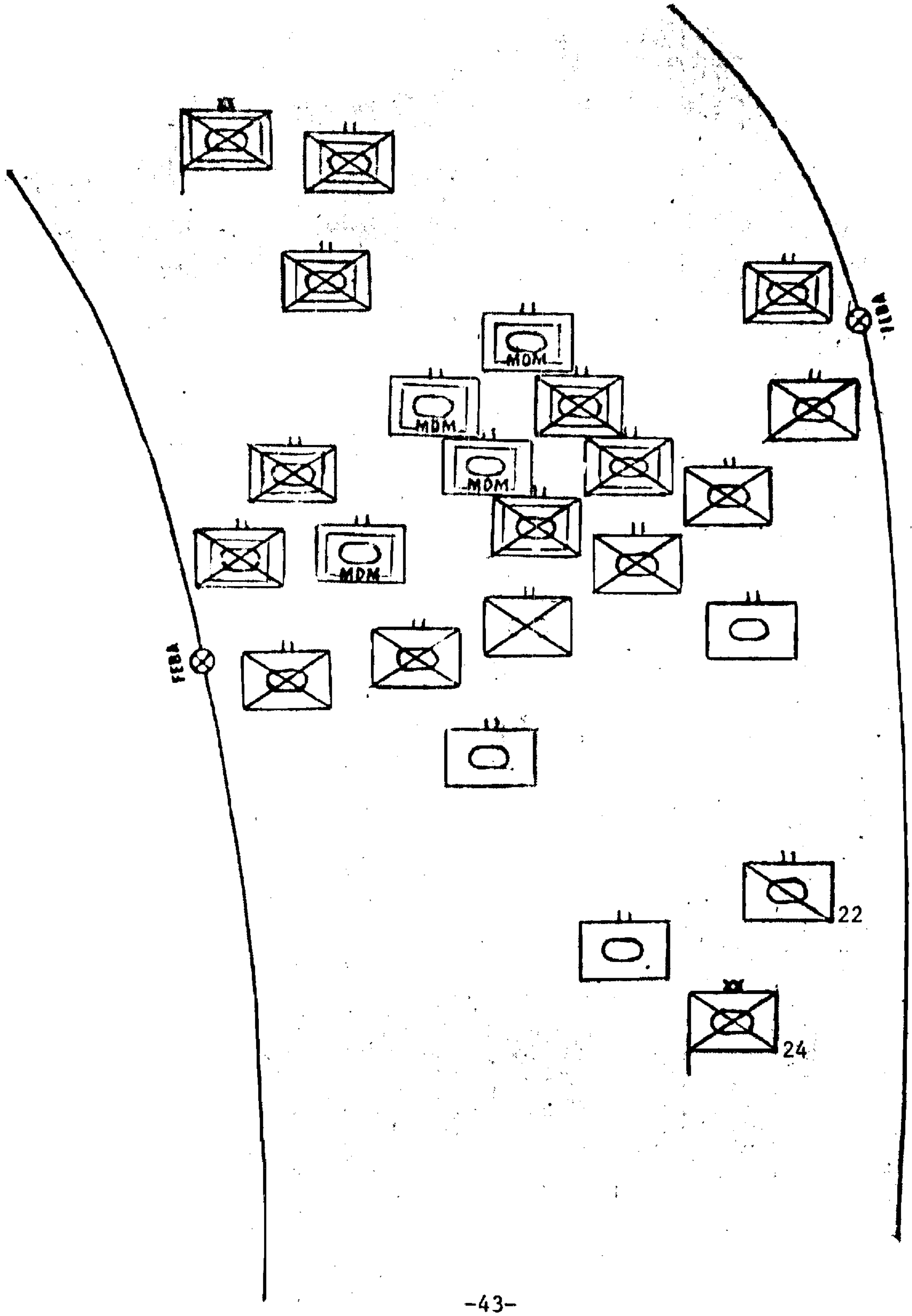
APPENDIX I

STRUCTURED MAP SCENARIO



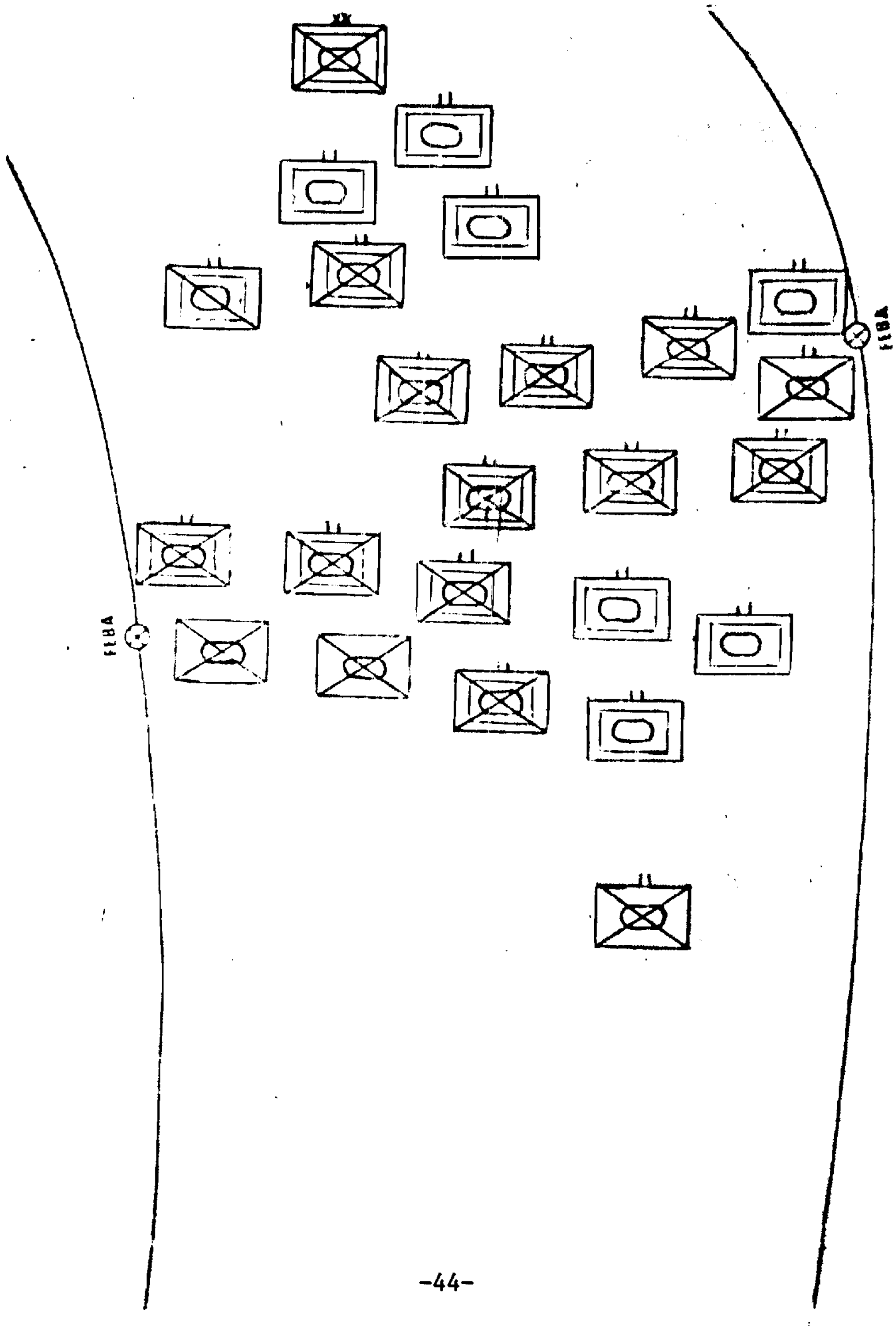
APPENDIX I

STRUCTURED II MAP SCENARIO



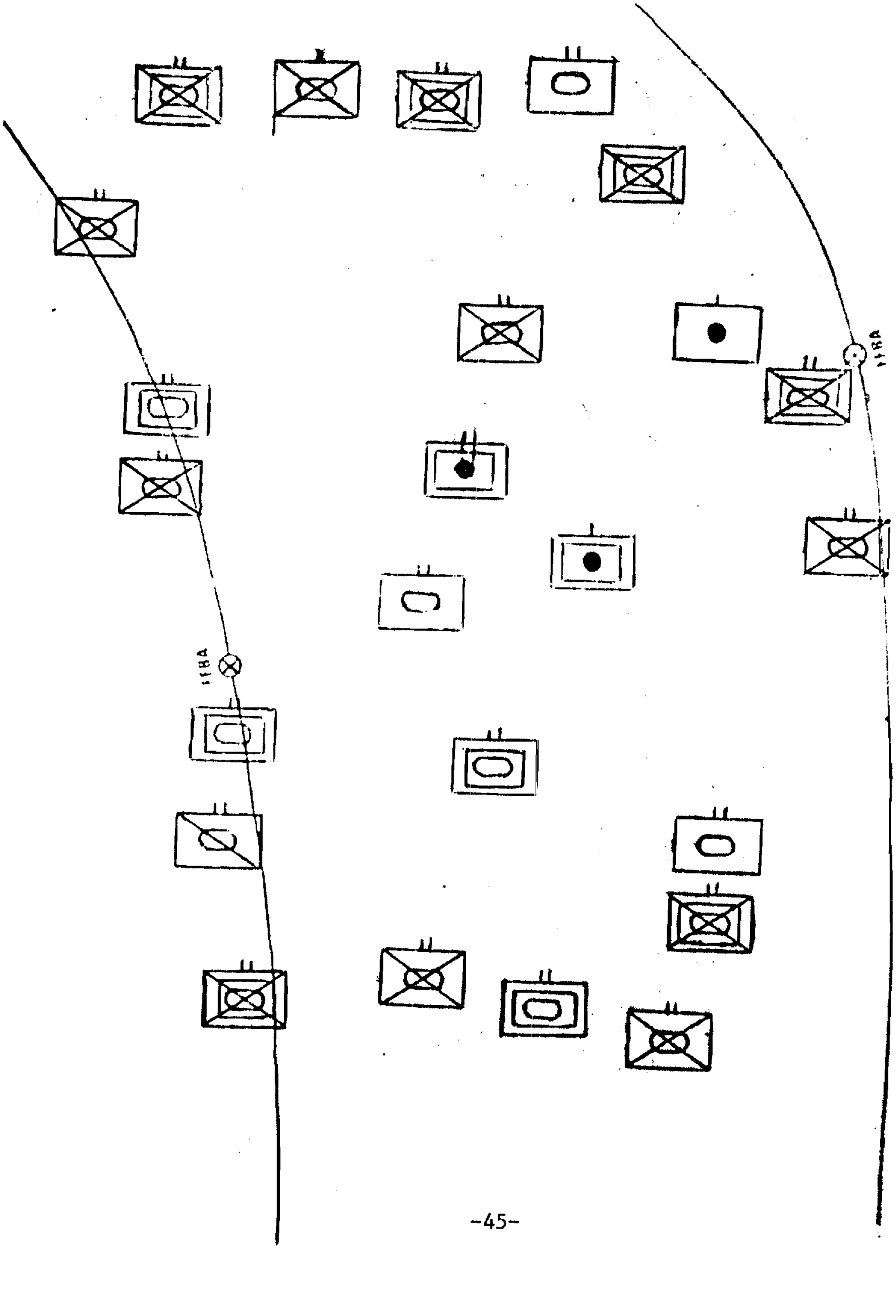
APPENDIX I

SEMI-STRUCTURED MAP SCENARIO



APPENDIX I

UNSTRUCTURED MAP SCENARIO



APPENDIX II

DEPARTMENT OF THE ARMY
ORGANIZATIONS AND SYSTEMS RESEARCH LABORATORY
U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 EISENHOWER AVENUE, ALEXANDRIA, VIRGINIA 22333

PERI-OS 17 March 1978

TO: Army Research Institute Participants

SUBJECT: Selecting and Representing Information Structures for Battlefield Decision Systems

1. Recent Army policy has been to reduce the "tooth-to-tail ratio" in organizational and personnel alignments. Part of this policy has included various methods of computerizing functions that formerly required many soldiers. Specifically, the Army Research Institute is addressing Command and Control systems [e.g. Tactical Operations System (TOS), Standoff Target Acquisition System (SOTAS), Computerized Artillery Support (TACFIRE) and Battlefield Exploitation and Target Acquisition (BETA)].

2. The one facet, of the myriad of challenges in developing such systems, that you will address today is the rapid and comprehensible display of tactical information for Command Decision Making.

3. The objective of the proposed research is to identify and apply experimental techniques for locating and valuating data patterns and informational chunks which are meaningful to the battlefield commander in his decision-making tasks. The identification of meaningful chunks of information is useful in specifying criteria for the development of decision-aiding algorithms that search for, classify, and display information. Also, a designation of the size and content of a meaningful chunk has a direct bearing on the design specifications of data frames for battlefield information systems.

The main drawback of systems developed to aid the decision-maker in his information processing activities has been the reliance of the programmer on his own intuitiveness or the unvalidated reports of experts as to how the task-information should be represented and structured. Accordingly, the plan is to develop and test a set of experimental techniques that may be used to specify how the battlefield decision-maker represents and structures the data of his problem.

PERI-OS
SUBJECT: Selecting and Representing Information Structures for Battlefield Decision Systems

The Experimental techniques to be used here follow in part from a well established line of research on human problem-solving and cognition to study how experts organize and chunk the information in a problem. In this experiment you will be faced with a problem-environment; you then will be asked to manipulate various object-symbols in this environment through tasks such as reconstructing or copying the symbols. The scientists will record certain key data then analyze the collected data to determine the characteristics of a chunk.

4. There are no right or wrong answers. You, along with other participants representing all levels of Command and Staff, are the experts that will aid in the design of the Command and Control Systems for the U. S. Army.

D. M. CANDLER
CPT, GS
R&D Coordinator

APPENDIX III

PERI-OS 17 March 1978

TO: ARMY RESEARCH INSTITUTE PARTICIPANTS

SUBJECT: Selecting and Representing Information Structures for Battlefield Decision Systems

1. Unique findings in data gathering are sometimes attributable to unique experience or educational backgrounds. To assist in validating data the following Biographic Information is requested.

2. In accordance with guidance concerning the Privacy Act, it is requested that you not put your name or social security number on these forms or any of the experiment information. Data from the experiment is associated with Bio-Data by Participant number only. No information associating participant name to participant number is used for analysis or any other purpose.

Biographical Information Participant #__________

Rank ________________ Years of Military Service __________ Age __________

OPMS Specialty Title ____

OPMS Alternate Specialty Title ____

Years of College/Degree ____

Years of Graduate School/Degree ____

Have you attended:

_____ Officer Advanced Course (Branch: ________________) Year ______

_____ Army Command & General Staff College (Ft. Leavenworth) Year ______

_____ National War College (Ft. McNair) Year ______

_____ Army War College (Carlisle Barracks) Year ______

_____ Tactical Map Exercises in West Germany Year ______

Please summarize your military experience in tactical units chronologically in the spaces below:

(Please check ( ) before year those assignments which included combat experience.)

( )	Year	Position Type (Cdr, S1,S2,S3,S4,etc)	Unit Type & Level (e.g., Mech Co)	Duration (Months)	Location

3. Your participation in this research is appreciated and important to the development of command and control systems.

D.M. CANDLER
CPT, GS
R&D Coordinator