Development of a Taxonomy of Human Performance:

Evaluation of an Abilities Classification System For Integrating and Generalizing Research Findings

Jerrold M. Levine
Tania Romashko
Edwin A. Fleishman

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WASHINGTON OFFICE
Address: 8555 Sixteenth Street, Silver Spring, Maryland 20910
Telephone: (301) 587-8201

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A preliminary evaluation of the effectiveness of a task classification system based upon human abilities for integrating and generalizing research findings was the focus of the present paper. The evaluation was designed to determine (a) the extent to which abilities could differentiate task performance and (b) the extent to which such performance could be differentiated with respect to selected independent variables. Fifty-three studies in the vigilance literature were analyzed in terms of abilities required for task performance. The studies were then classified according to one of four predominant abilities.

The results showed that different functional relationships between performance and time in the vigil were identified for tasks representing the different ability categories. When studies falling into two of the primary ability categories were partitioned according to levels of three independent variables, marked differences in the functional relationships between performance accuracy and time in the vigil were noted for each independent variable as a function of abilities. A stringent ability rating criterion was used for accepting studies into each of two primary ability categories. In one case, the functional relationship was almost identical to that obtained under a less stringent rating criterion, while in the other case the relationship was altered. Tasks were also classified in terms of a primary ability required in conjunction with a secondary ability. The functional relationships which resulted were different from those describing task performance and time in the vigil when classified strictly by a primary ability.

Based on these findings, the abilities approach to task classification seems a viable and useful one. Functional relationships were revealed which would have been

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obscured had the tasks not been classified by the abilities required. Generalizations about the effects of independent variables on vigilance were enhanced by the approach used. Predictions of performance on new tasks, as a function of these variables, should be facilitated by the application of the task classification system. It was recommended that additional efforts be undertaken to ascertain whether abilities will also prove useful in organizing a more heterogeneous area of experimental literature, using a broader set of abilities.

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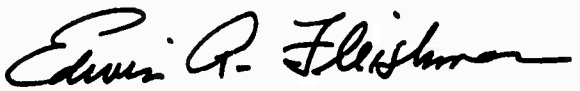
PREFACE

The AIR Taxonomy Project was initiated as a basic research effort in September 1967, under a contract with the Advanced Research Projects Agency, in response to long-range and pervasive problems in a variety of research and applied areas. The effort to develop ways of describing and classifying tasks which would improve predictions about factors affecting human performance in such tasks represents one of the few attempts to find ways to bridge the gap between research on human performance and the applications of this research to the real world of personnel and human factors decisions.

The present report is one of a series which relates to work undertaken during the first three years of project activity. In 1970, monitorship of the project was transferred from the Air Force Office of Scientific Research (AFOSR) to the U. S. Army Behavior and Systems Research Laboratory (BESRL), under a new contract. This effort, accomplished under the new contract, is among several describing developmental work. The report is also being distributed separately as a BESRL Research Study.



EDWIN A. FLEISHMAN
Senior Vice President and
Director, Washington Office
American Institutes for Research

FOREWORD

The American Institutes for Research is engaged in a research program to develop and evaluate new systems for describing and classifying tasks which can improve generalization of research results about human performance and to develop a common language for researcher-decision maker communication that would help organize human performance information for maximum use in training, equipment design, and personnel selection.

The objective of this program is to develop theoretically-based language systems (taxonomies) which--when merged with appropriate sets of decision logic and appropriate sets of quantitative data--can be used to make improved predictions about human performance. Such taxonomies should be useful, for example, when future management information and decision systems are designed for Army use.

The present publication reports on an effort to evaluate the usefulness of a system for improving the extent to which research findings about task performance can be generalized. An abilities classification system was applied to existing data concerned with vigilance performance. It was shown that the functional relationships describing performance with time in the task, in general, and for selected independent variables were different for the different ability categories. Implications for integrating disparate research findings and for developing a data base are described.

J. E. UHLANER, Director
U. S. Army Behavior and Systems
Research Laboratory

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DEVELOPMENT OF A TAXONOMY OF HUMAN PERFORMANCE: EVALUATION OF AN ABILITIES CLASSIFICATION SYSTEM FOR INTEGRATING AND GENERALIZING RESEARCH FINDINGS

BRIEF

Requirement:

The development and evaluation of systems for describing and classifying tasks which can improve generalization of research results about human performance is essential for organizing, communicating, and implementing these research findings. The present research was undertaken to assess the feasibility of constructing a data base founded on an abilities classification system, which could improve generalizations of research results about human performance.

Procedure:

A preliminary evaluation of the usefulness of an abilities approach to task classification was the focus of the present paper. The evaluation was designed to determine (a) the extent to which abilities could differentiate task performance and (b) the extent to which such performance could be differentiated with respect to selected independent variables. Sixty studies in the vigilance literature were analyzed in terms of the abilities required for task performance. The studies were then classified according to one of four predominant abilities.

Findings:

Different functional relationships between performance and time in the vigil were found for the four ability categories. When studies falling into two of the primary ability categories were partitioned according to levels of three selected independent variables, marked differences in the functional relationships between performance accuracy and time in the vigil were noted for each independent variable as a function of abilities. A stringent ability rating criterion was then

used for accepting studies into each of two primary ability categories. In one case, the functional relationship was almost identical to that obtained under a less stringent rating criterion, while in the other case the relationship was altered. Tasks were also classified in terms of a primary ability in conjunction with a secondary ability. The functional relationships which resulted were different from those describing task performance and time in the vigil when classified strictly by a primary ability.

Utilization of Findings:

Based on these findings, the abilities approach to task classification seems a viable and useful one. It was recommended that additional efforts be undertaken to ascertain whether an abilities taxonomy will also prove useful in organizing a more heterogeneous area of experimental literature, one in which a broader set of abilities would be required for performance.

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INTRODUCTION

There is a continuing need to make more effective use of behavioral data generated by human performance research. This need is intensified as more research is conducted and the available body of human performance literature grows. In particular, we need better ways to generalize research findings from laboratory studies to operational settings, from one experimental study to another, and from one operational situation to another. There are serious limitations in the extent to which we can do this in the human performance area. As a result, it is difficult for those in operational settings to make predictions about factors affecting human performance from knowledge of the performance research literature. Similarly, it is difficult for researchers to develop general principles about factors affecting human performance which can serve as a basis for further theoretical and scientific development.

The assumption underlying the work in the present program is that a system for classifying tasks can be developed which would allow more dependable prediction of the effects of independent variables on task performance within and between classes of tasks. Such a system would be especially valuable in making most effective use of available data and for predicting performance on new tasks. The development of such a taxonomic framework, employing a language for describing tasks common to many different basic and applied areas, should improve communication among researchers and applied personnel and help organize human performance information. An additional benefit deriving from such a taxonomy is the identification of gaps in existing knowledge, where future research can be directed on how given factors affect human performance.

In response to this need, a major program of research concerned with the development of a task taxonomy of human performance was undertaken. Research has proceeded along several lines. Literature reviews by Farina (1), Theologus (2), and Wheaton (3) suggested a variety of descriptive systems varying from highly detailed and specific categorical sets to general categories frequently seen in the experimental literature (e.g., cognitive and motor skills). Neither highly specific nor highly general categories were deemed likely to be useful in permitting generalizations of principles across tasks. Furthermore, none of the various descriptive systems had been empirically evaluated in terms of the extent to which they are useful in improving generalizations and predictions about aspects of human performance.

The lack of any existing taxonomic system considered appropriate for structuring human performance literature led to the development of several provisional classification systems. The rationale underlying each system concerned the kinds of common dimensions involved in task performance. Systems were developed based upon: task characteristics by Farina and Wheaton (4); human abilities by Theologus, Romashko and Fleishman (5), and Theologus and Fleishman (6); information theory by Levine and Teichner (7); and task strategies by Miller (8). The abilities and task characteristics approaches have undergone preliminary testing by Theologus, Romashko and Fleishman (5) and Farina and Wheaton (4) to determine the reliability with which individuals can rate task descriptions. A subsequent evaluation of the abilities approach by Theologus and Fleishman (6) demonstrated some success in predicting empirical factor loadings and performance levels on tasks. Farina and Wheaton (4) also accomplished prediction of performance levels on a variety of tasks for the task characteristics approach.

An evaluation of the usefulness of a taxonomic system is also provided by its capability to structure a body of literature and to organize it more meaningfully. One line of work in the present project

has already provided a preliminary evaluation of a task classification system, based on criterion performance measures common to broad classes of tasks. The task classification system was applied to a portion of existing literature dealing with optimum distribution of practice, knowledge of results, and the effects of different noise intensities. This classification system, developed by Teichner and Olsen (9), consisted of a few broad categories of task performance defined by dependent measures. For example, the performance class called "switching" was defined by measures indicating the latency of the operator's response, whereas "coding" was defined by the percentage of correct responses made by the operator during task performance. The results of the evaluation study by Teichner and Whitehead (10) indicated that such task categories were useful in helping to predict performance data obtained with such tasks. Furthermore, it was possible to plot functional relationships within certain categories which held across a variety of tasks. For example, the function describing the relationship of interval between practice sessions to performance depended on the task category. Knowledge of the task category allowed improved prediction of performance level, given the interval between practice sessions. Had the tasks not been classified according to the descriptive system, the relations would have been obscured. These results are encouraging with respect to the utility of taxonomic systems in integrating research data now available on a variety of different tasks.

The evaluation of a taxonomic system in terms of its capacity to organize a portion of literature constitutes the focus of this report. The objective of the present effort was the preliminary assessment of the feasibility of classifying an area of literature according to the "abilities" required for task performance. Specifically, the study was designed to determine the extent to which abilities could differentiate task performance in general and the extent to which such performance could be further differentiated with respect to selected independent variables. Functional relationships across studies were also evaluated.

Research in the area of sustained attention was selected for study in order to determine whether the ability classification system would allow more dependable generalizations about factors affecting vigilance.

The ability classification system has undergone considerable developmental research and evaluation. Of particular importance for the present effort is the empirical development of anchored scales and the derivation of reliability estimates of employing the ability system to classify tasks accomplished by Theologus, Romashko and Fleishman (5). Earlier, Fleishman (11, 12) recognized the potential of ability categories for the development of a behavioral taxonomy. He (12) recommended the application of a consistent set of performance categories to a body of literature in order to ascertain if greater consistency in establishing principles relating treatments to classes of human performance would result. The present study accomplished such an application.

The present effort has important implications for future research. If the feasibility of this approach can be demonstrated by the limited specific effort carried out in the present study, a major study would be justified to structure other human performance literature areas employing a larger set of abilities. Should the ability approach prove effective in this in-depth study, the development of a data base, structured on the ability classification system, could be undertaken for the purpose of integrating and generalizing research findings.

METHOD

The ability approach to task classification describes tasks in terms of abilities required for performance. Abilities are general traits of the individual which provide him with the capacity to perform different tasks. Human abilities are derived primarily from reported factor analyses of human performance in the cognitive, psychomotor, physical, perceptual, and sensory areas. These abilities are inferred from intercorrelations among performances on a selected group of tasks.

In previous work on the project, an ability classification system has been developed and a reference manual prepared by Theologus, Romashko and Fleishman (5). The manual, entitled "Task Assessment Scales (TAS)," allows raters to apply these scales to tasks. The TAS consists of thirty-seven categories which represent four performance domains. Fourteen abilities are in the cognitive domain, five in the perceptual-sensory domain, eight in the physical proficiency domain, and ten in the psychomotor domain. Each ability is defined so as to express its precise nature in operational terms and to reveal its scope and limits (see Appendix I). A 7-point scale is used in determining the extent to which an ability is involved in task performance. A scale value of seven represents a maximum amount of the ability, four a moderate amount, and one a minimum amount. Definitions of high and low levels of each ability are presented to the left of the scale. Each scale has been anchored by three specific examples of performance requiring different amounts of the ability. The exact scale values of each example on the scale have been empirically determined.

Application of the ability classification system to the analysis of a particular task involves two basic decisions by the individual rating the task: (1) Is the ability required for performance, and (2) if the answer is "yes," what is the extent to which the ability is involved in task performance? A determination is made by use of the 7-point rating scale. This procedure is followed for each ability contained in the TAS

for the analysis of any task. The present study utilized this system for describing the tasks employed in previous studies of vigilance.

Selection of a Content Area

A set of objective criteria was developed to serve as a basis for the selection of an area of literature to which the abilities taxonomy would be applied. Two premises underlie the criteria which were established. One was to maximize the likelihood that abilities could be employed to effectively classify tasks. The second concerned the existence of a relatively stable set of principles relating the effects of independent variables to performance. Thus, known results of the effects of different independent variables would be available for comparison purposes with the ability classification results. Six criteria were used to select a literature area.

First, inclusion of overlearned tasks in the literature area was deemed essential in order to eliminate learning effects. Fleishman (12) has demonstrated that abilities required for task performance change as a function of learning. However, these changes are progressive, systematic, and eventually become stabilized. Second, it was desirable to include a variety of tasks in the literature area. This criterion promoted the potential differentiation of task performance by ability categories because different types of tasks would tend to require different abilities for task performance.

The number of abilities required for task performance led to a third criterion. That is, a limited set, less than the 37 which comprise the entire system, was considered appropriate for a preliminary evaluation. This constraint reduced the need to review all 37 abilities for each research study. A fourth criterion was the desire to include ability categories from more than one of the four ability domains (cognitive, perceptual-sensory, physical, and psychomotor) in order to permit comparisons of abilities across domains. It was felt that consideration of abilities within a single domain would provide too restrictive an evaluation.

A fifth criterion involved the specification of independent variables. To allow for the separation of ability classifications according to independent variables, several frequently studied independent variables within a content area had to be available. Further, the effects of such variables on performance must have been generally well-defined and consistent. A final criterion was the existence of a primary dependent variable for the content area.

These criteria were applied to twelve content areas. The literature on vigilance emerged as the area which best met the criteria, with the exception of the criterion dealing with task heterogeneity. However, task homogeneity provides a more stringent test of the ability classification system. If performance differentiation by abilities could be achieved for vigilance, then differentiation of an area with more heterogeneous tasks could certainly be expected.

Characteristics of Vigilance

Vigilance is defined by Bergum and Klein (13) as a change in performance, over prolonged periods of time, in the detection of infrequent signals, which are temporally and spatially random in character. The characteristic finding in vigilance tasks is the deterioration of performance with time. This phenomenon is referred to as the vigilance decrement.

Familiarity with the vigilance literature permitted the selection of three independent variables known to have been frequently manipulated across studies and to have demonstrated generally consistent effects. It is important to note that the effect of any independent variable on vigilance performance is illustrated by an interaction of the variable with time in the vigil. Main effects indicate only that overall performance differs among levels of the manipulated variable, not that the variable has had any influence on the vigilance decrement. Therefore, our interest will be concentrated upon interactions. The three independent variables selected were signal rate, sensory mode, and knowledge of results.

Signal rate is defined by the number of signals presented per selected time interval. Performance in a vigilance task is generally enhanced by increased frequencies of signal presentation (see, for example, Jenkins (14), Kappauf and Powe (15), and Colquhuon (16)). To assess the effects of signal rate on performance, three levels of the variable were defined: Low (less than one signal per minute), Moderate (one to two signals per minute), and High (more than two signals per minute).

Sensory mode involves consideration of the sense modality in which signals are presented. Research on this variable has tended to concentrate on the visual and auditory modalities; specifically, the presentation of visual only signals, auditory only signals, or both visual and auditory signals presented simultaneously. In general, visual-auditory redundant presentation of signals usually elicits better performance than either single mode auditory or visual presentation. Single mode auditory presentation of signals is usually better than single mode visual presentation. Studies by Buckner and McGrath (17), Osborn, Sheldon and Baker (18), and Gruber (19) illustrate these results.

Knowledge of results concerns whether or not some form of feedback was provided on task performance during the course of the vigil. As expected, feedback generally improves overall detection performance. Mackworth (20) first demonstrated the beneficial effects of knowledge of results on performance in a vigilance task. Additional studies by Garvey, Taylor and Newlin (21), Wilkenson (22), and Hardesty, Trumbo and Bevan (23) have indicated a general enhancement of performance in a variety of vigilance tasks. The dichotomy "knowledge of results" and "no knowledge of results" constituted the two levels of this variable.

Selection of Abilities

Since vigilance entails the detection of infrequent, randomly appearing signals over a prolonged time period, the main ability domains considered were perception and cognition. The nature of vigilance performance precludes the involvement of physical abilities and minimizes

the importance of psychomotor abilities. Within each of the two ability domains, two primary ability categories were selected as best representing aspects of vigilance performance.

The two abilities in the perceptual domain and their respective definitions were:

- Perceptual Speed: The speed with which sensory patterns or configurations are compared in order to determine identity or degree of similarity. Comparisons may be made either between successively or simultaneously presented patterns or configurations, or between remembered or standard configurations and presented configurations. The sensory patterns to be compared occur within the same sense and not between senses.

- Flexibility of Closure: The ability to identify or detect a previously specified stimulus configuration which is embedded in a more complex sensory field. It is the ability to isolate the specified relevant stimulus from a field where distracting stimulation is intentionally included as part of the task to be performed. Only one information source is utilized. This ability applies to all senses with the restriction that both the relevant and distracting stimulation must occur within the same sense modality.

The abilities and their definitions in the cognitive domain were:

- Selective Attention: The ability to perform a task in the presence of distracting stimulation or under monotonous conditions without significant loss in efficiency. When distracting stimulation is present in the task situation, it is not an integral part of the task being performed but rather is extraneous to the task and imposed upon it. The task and the irrelevant stimulation can occur either within the same sense or across senses. Under conditions of distracting stimulation, the ability involves concentration on the task being performed and filtering out of distracting stimulation. When the task is being performed under monotonous conditions, only concentration on the task being performed is involved.

- Time Sharing: The ability to utilize information obtained by shifting between two or more channels of information. The information obtained from these sources is either integrated and used as a whole or retained and used separately.

Determination of Ability Rating Criteria

To maximize the likelihood of differentiating task performance as a function of abilities and identifying relationships between abilities and performance with respect to independent variables, ability rating criteria had to be established. The development of such criteria focused upon the most prominent ability considered necessary to perform a task. Only those studies meeting the criteria were included in the set of studies to which the classification system was applied.

The representation of a minimum critical rating value of an ability was accomplished by choosing a value on the 7-point scale used for rating abilities. A "7" indicated the maximum level of an ability. Few tasks were likely to require this extreme amount. Although a somewhat larger number of tasks could require a "6," this value might still be excessively restrictive. A "5" seemed to be the best choice since it indicated a level higher than moderate but, at the same time, was not severely limiting. In addition, the predominant ability was considered in relation to other abilities judged as necessary for performance. It was decided that the predominant ability must be rated two scale points higher than the next highest rated ability. The task had to be rated in terms of the predominant ability at a level of at least 5 or have a value two scale points higher than the next highest rated ability.

Selection of Research Studies

Identification of bibliographic citations of vigilance studies was accomplished through a literature search. Primary information sources included reviews and bibliographies of the vigilance literature, Psychological Abstracts, and Index Medicus. Consideration was only given to articles published during the past twelve years.

Of the 195 articles identified through this procedure, criteria for study acceptance were developed, then applied. These criteria included adequacy of task description, manipulation of independent variables of interest, use of the performance measure probability of detection or a similar measure, and presentation of performance data over time. Quality filtering of the studies according to these criteria yielded 60 acceptable studies (see Appendix II). Of the 135 studies eliminated, 20% were rejected because they used performance measures which could not be transformed to probability of detection, 19% were rejected because they failed to present performance data over time, and 61% were rejected either because none of the pre-selected independent variables were manipulated, or the task description was not presented in sufficient detail, or the experimental procedures were inappropriate or inadequate.

Data Extraction Procedures

To gain comparability of information across studies included in the literature, the data recorded for each study was standardized. A coding form (see Appendix III) was developed to permit the recording of all pertinent information from each study. It contained the following informational components:

- Complete bibliographic citation.
- Report abstract or author's summary.
- Listing of all independent variables used and the number and specification of levels.
- Listing of all performance measures employed, including operational definitions of each.
- Length of overall vigil and individual trials plus the number of signals presented per trial.
- Estimation of abilities required for task performance, their rating, and relative ranking in order of importance.

- Major details of the task description.
- Listing of significant results, level of significance, and specific significant comparisons.
- Average performance on the task by various levels of the independent variables across trials for all performance measures.

A final review of the resultant data set was then conducted. The purposes served by this review were to (a) verify that each study met all of the criteria established, and (b) identify and eliminate any of the studies containing data anomalies.

The set of acceptable studies was further reduced. Two studies were rejected because they failed to meet either of the ability rating criteria. Three studies in which performance on the initial trial fell below 50% detected were eliminated on the grounds that this was only chance detection. The only study reporting rest periods between trials was eliminated on the basis of contamination of vigilance performance results. The number of studies remaining was 54.

Where necessary, data was standardized to reflect probability of detection. Means and medians were computed for each study across all levels of all independent variables to provide average task performance over trials. Data was also averaged for each of the pre-selected levels of the three independent variables of interest.

To permit the maximum amount of data from each study to be used in the analysis phase, performance was considered for ten-minute segments up to three hours. Only two studies exceeded the three-hour limit. In one case, only data within the three-hour period was used. In the other case, the study was eliminated because only one data point existed within the three-hour period. Thus, the number of studies included in the final set was 53.

RESULTS AND DISCUSSION

A variety of analyses were performed on the 53 experimental studies to provide information about the effectiveness of the abilities approach to the classification of vigilance studies. The primary objective of these analyses was to determine whether or not the relationship between performance and time in the task could be differentiated as a function of the four ability categories, i.e., Perceptual Speed, Flexibility of Closure, Attention, and Time Sharing.

As a preliminary step, studies were divided into the four ability categories based on the predominant ability required for task performance. This yielded 25 data sets for Perceptual Speed, 25 data sets for Flexibility of Closure, 6 for Attention, and 2 for Time Sharing. There was a larger total number of data sets than studies since several studies reported multiple experiments. Within each category, the percentage of studies which showed an increment, no change, or a decrement in performance over trials was computed. Further, studies in which results were statistically significant were differentiated from studies which simply demonstrated a trend in the indicated direction. In this analysis, as in all subsequent analyses to be discussed, the results for Attention and Time Sharing ability categories must be viewed with caution and only as preliminary suggestions since the number of studies falling into these two categories was quite small.

General Findings on Performance Decrement

Within the Perceptual Speed category, 85% of the studies showed a performance decrement trend over time in the vigil. However, when viewed in terms of statistical significance, only 50% of the studies showed such a performance decrement, while 40% indicated no significant change at all with time in the task. A similar set of results was obtained for the Flexibility of Closure category in which 83% of the studies indicated a decrement. Fifty percent of the studies evaluated showed a

statistically significant performance decrement, while 45% of them showed no significant performance change. All of the studies falling into the Attention category indicated a performance decrement over time; however, only 33% of these were statistically significant. The remaining studies showed no significant change in performance over time. Studies falling into the Time Sharing category were too few to allow any meaningful generalizations to be made.

Overall, most of the studies evaluated showed performance decrements with time in the task. However, a far smaller percentage of them provided evidence of statistically significant performance decrements over time. The ratio of studies demonstrating significant performance decrements to those exhibiting no significant change in performance varied according to ability category. The greatest difference in favor of significant performance decrements was for studies falling into the Perceptual Speed category. For the Flexibility of Closure category, studies were nearly equally divided between a significant performance decrement and no significant performance change. A greater proportion of studies in the Attention category exhibited no significant change in performance rather than a significant performance decrement.

In most of the subsequent analyses to be discussed, data are presented for the first 90 minutes of the vigil rather than for the 180-minute time period for which data were available. In these instances, data beyond the 90-minute limit was too sparse to warrant analysis. For those cases where data are presented across the 180-minute course of the vigil, limited data were available. Regardless of whether data are presented for 90 minutes or 180 minutes, they have been divided into 10-minute intervals.

Classification in Terms of Abilities

The primary analysis performed was the computation of median percent correct detections at each ten-minute interval through the first 90 minutes of the vigil for all studies categorized according to one of

the four predominant abilities required for task performance. Figures 1-4 depict these median points along with the range of values dispersed around the medians for Perceptual Speed, Flexibility of Closure, Attention, and Time Sharing, respectively. Smooth curves were fitted by eye to these points. The graphs depict percentage correct detections as a function of time in the vigil for each of the four ability categories. In these, as well as the following figures, the curves were fit by considering the number of data points going into each median value. The greater the number of data points, the larger the impact of the median point on the specification of the curve.

Comparisons among the four functions indicated differences in performance over time for tasks in which the predominant ability was different. For tasks in which the predominant ability was Perceptual Speed, Figure 1 suggests that the performance decrement occurred primarily within the first hour of the vigil and subsequent time in the task led to no further performance deterioration. Figure 2, dealing with tasks involving the predominant ability of Flexibility of Closure, suggests that after the initial hour of performance degradation (which is similar to that shown in Figure 1), performance began to be enhanced with time in the vigil. Furthermore, the range of values about the median points demonstrates that tasks requiring Perceptual Speed resulted in greater performance variability than did tasks involving Flexibility of Closure. In both Figures 1 and 2 initial performance levels were approximately 80%, and deteriorated to about 65% by the end of the first hour. Beyond 60 minutes, performance on Perceptual Speed tasks remained at about 65% accuracy while performance for tasks requiring Flexibility of Closure increased to a level approximating initial performance.

Figures 3 and 4, for the abilities of Attention and Time Sharing, respectively, are based on far fewer points than were Figures 1 and 2. Smooth curves fitted to the median points for both of these ability categories suggest that the decrement in percent detection leveled off

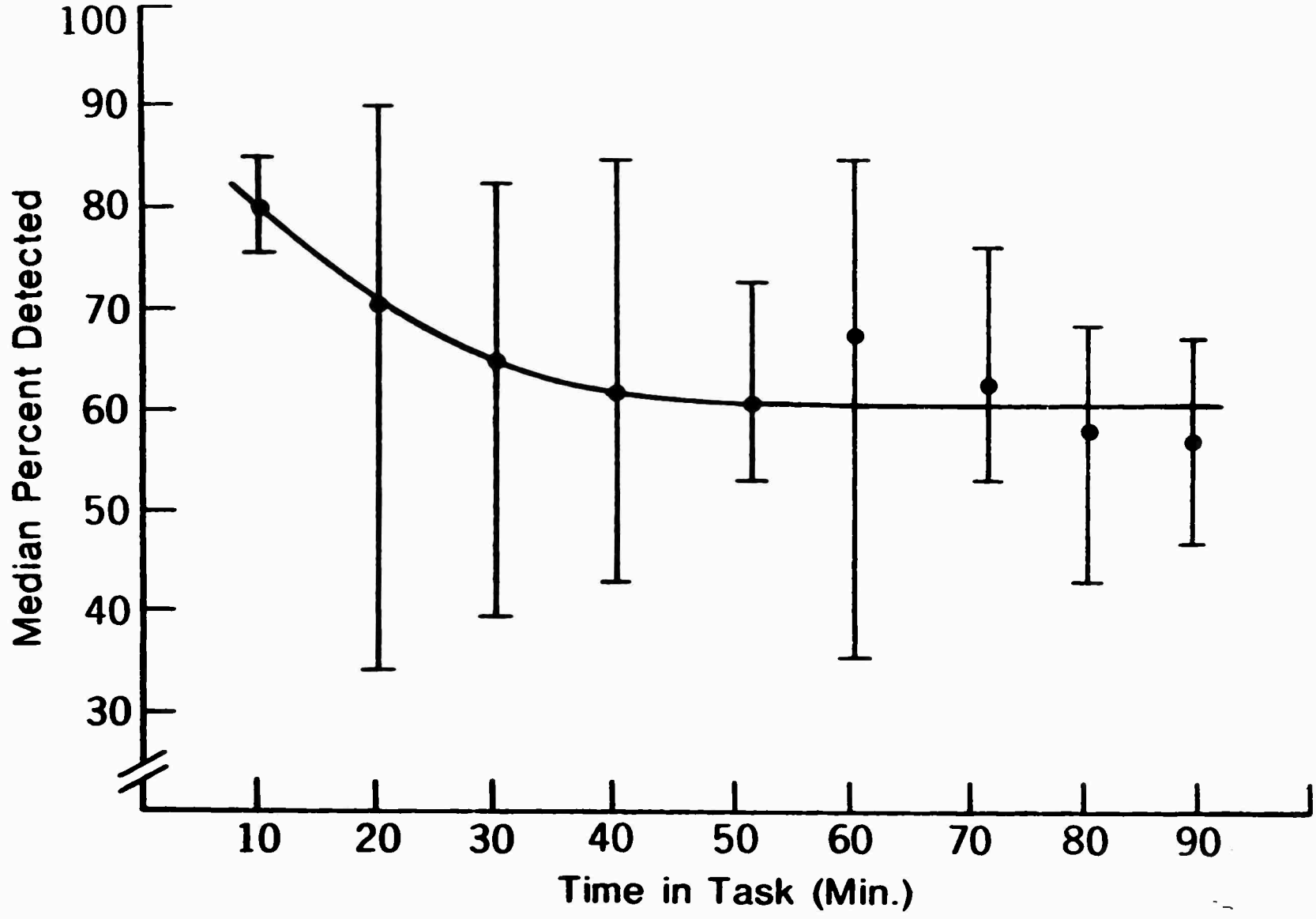

Figure 1. Median percent correct detections as a function of time in the task for studies in which the predominant ability was Perceptual Speed

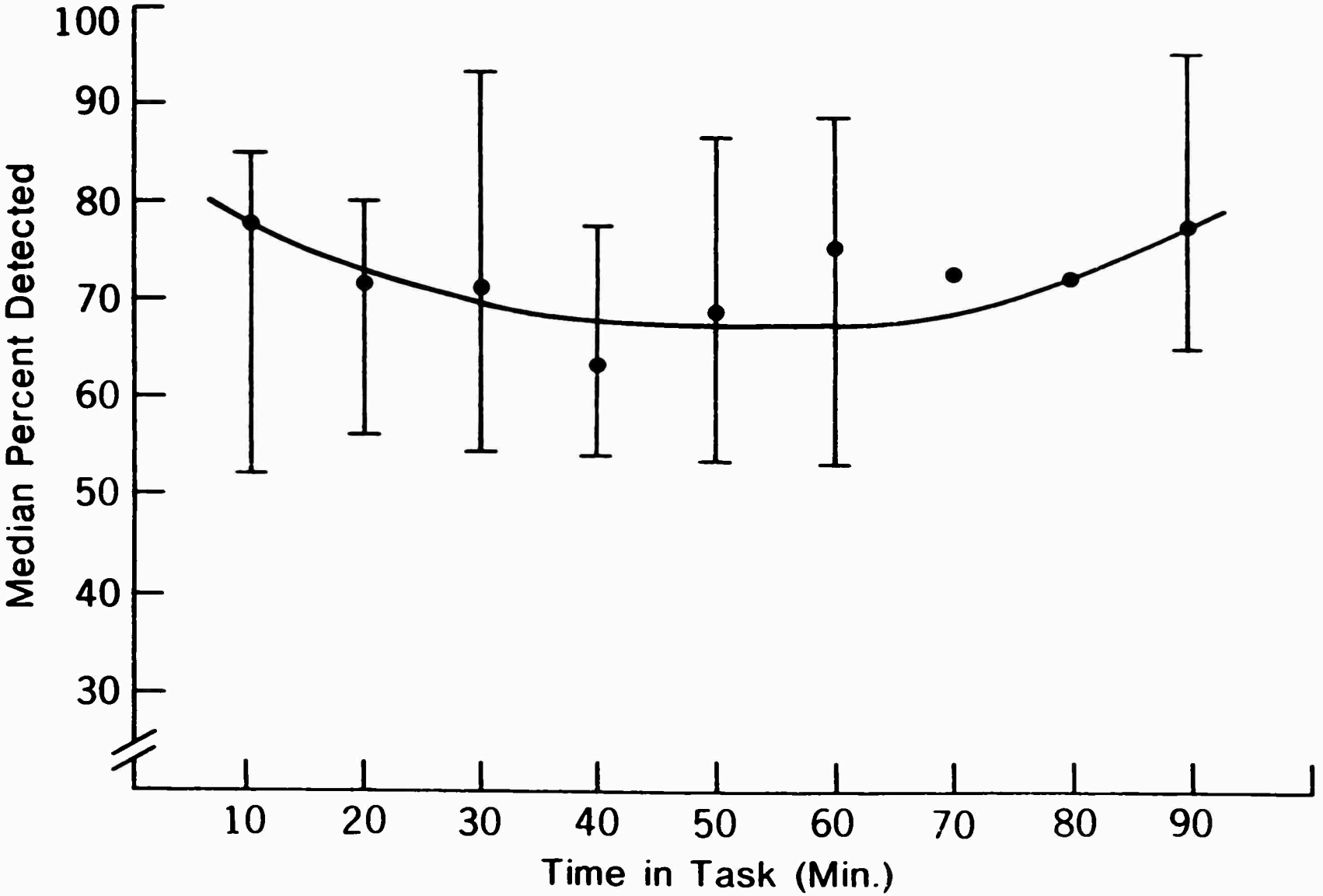

Figure 2. Median percent correct detections as a function of time in the task for studies in which the predominant ability was Flexibility of Closure

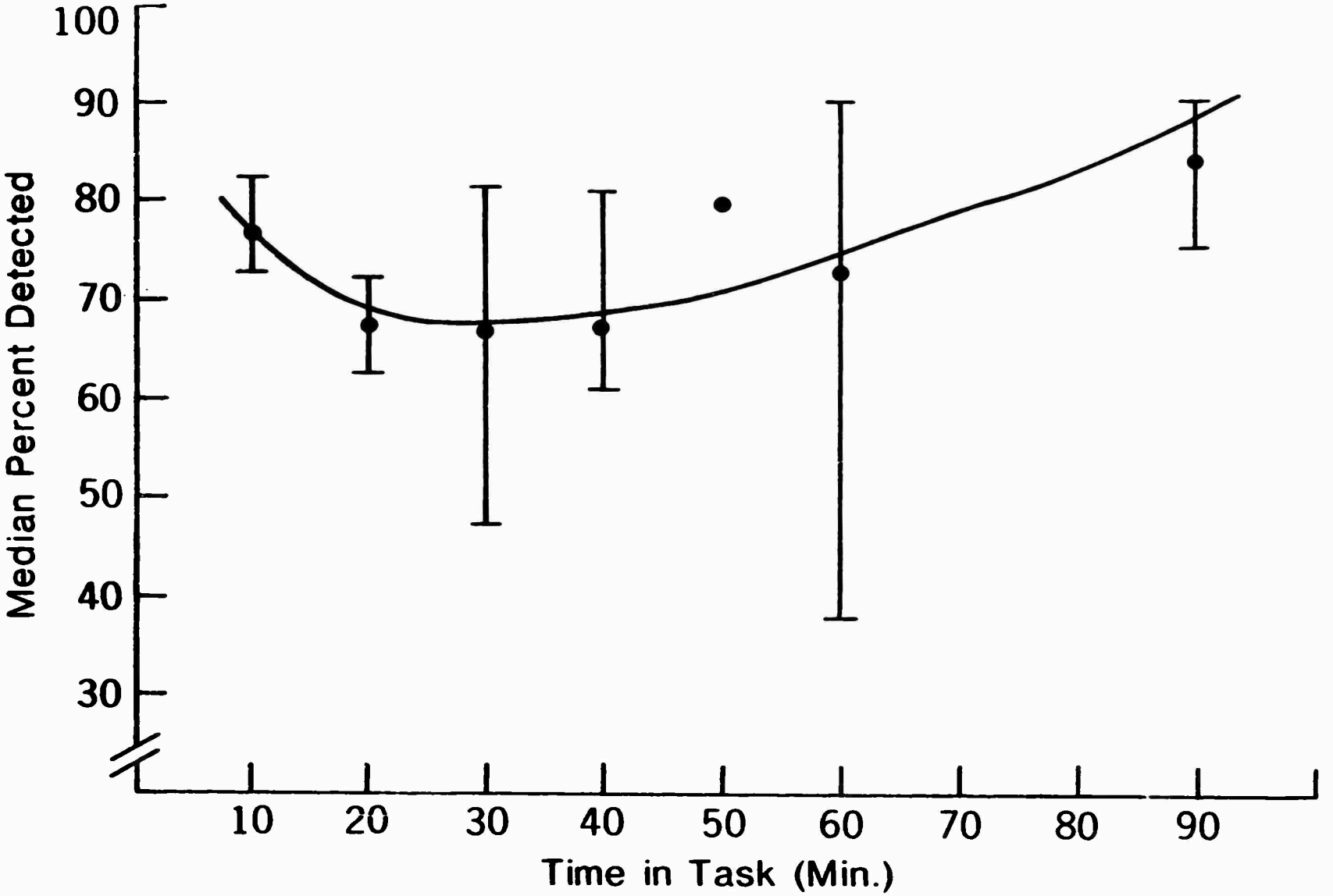

Figure 3. Median percent correct detections as a function of time in the task for studies in which the predominant ability was Attention

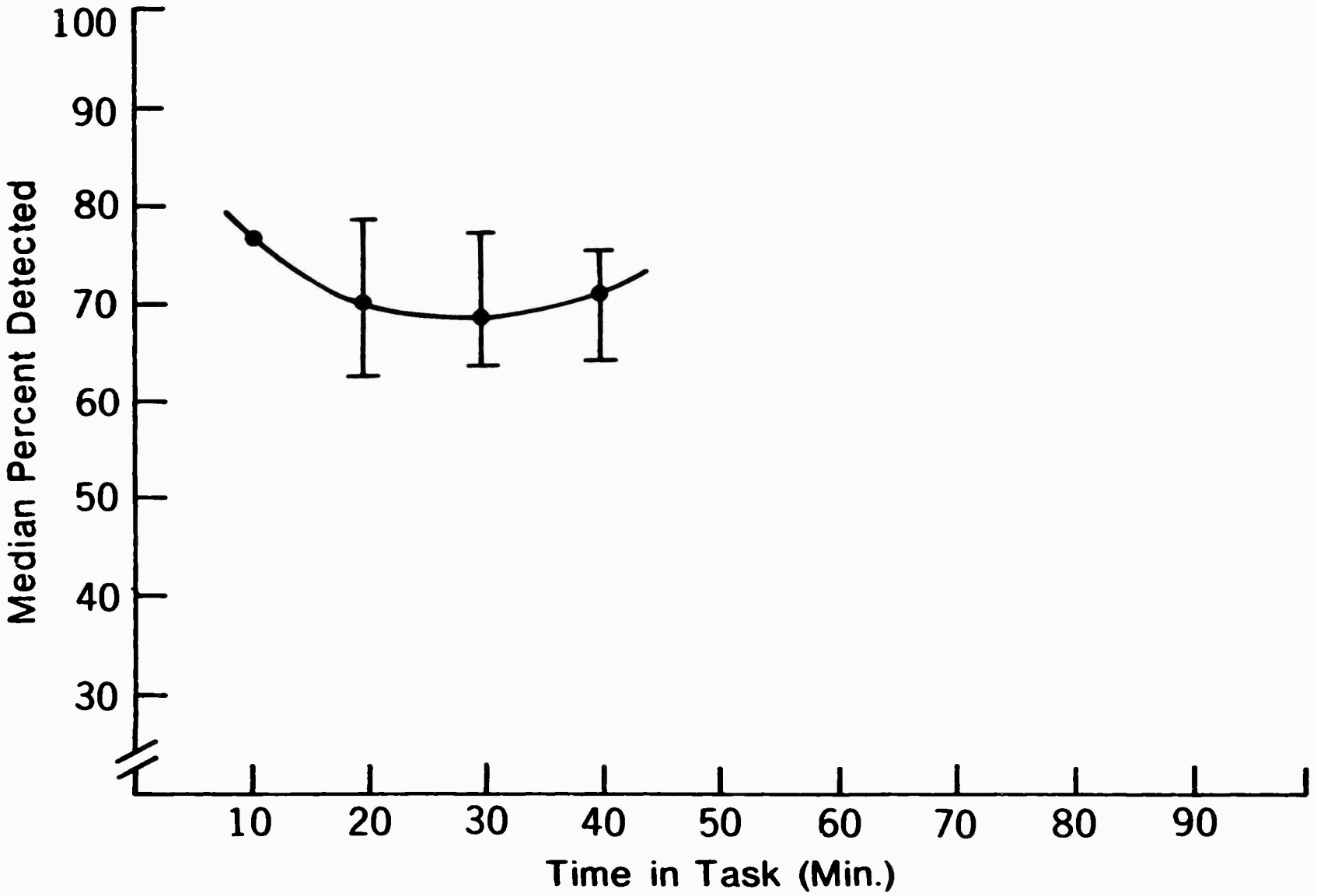

Figure 4. Median percent correct detections as a function of time in the task for studies in which the predominant ability was Time Sharing

after approximately 30 minutes, beyond which time performance improved. Except for the fact that there were no data points beyond 40 minutes for Time Sharing studies, the curves for Attention and Time Sharing are strikingly similar. The primary difference between these plots is that greater variability in performance was exhibited for studies in the Attention category than for studies in the Time Sharing category. The performance decrement for Attention and Time Sharing studies is similar to that found for Perceptual Speed and Flexibility of Closure tasks, i.e., initial accuracy was about 80% and deteriorated to 65% after 30 minutes in the vigil.

Consideration of all four figures suggests that performance in a vigilance task deteriorates up to a certain point in time, then begins to be enhanced when vigilance tasks require the abilities of Flexibility of Closure, Attention, or Time Sharing. However, when tasks require Perceptual Speed as the predominant ability, the performance decrement levels off but does not reverse (at least for the first 90 minutes of the vigil).

Classification by Abilities and Independent Variables

The data contained in Figures 1 and 2 were partitioned according to levels of each of the three selected independent variables. Figure 5 depicts percent correct detection as a function of time in the vigil with signal rate as a parameter for tasks requiring the predominant ability of either Perceptual Speed or Flexibility of Closure. For each ability category, performance medians were computed at 10-minute intervals through the first 90 minutes of the vigil for the low, moderate, and high rates of signal presentation. Functions were generated by fitting curves by eye to each set of median points. At all three levels of signal rate, obvious differences exist in the functional relationships between time in the vigil and performance for the two ability categories.

For low signal rates, performance on Perceptual Speed tasks decreased linearly with time in the task, while performance on Flexibility of Closure tasks demonstrated a sharp decrement early in the

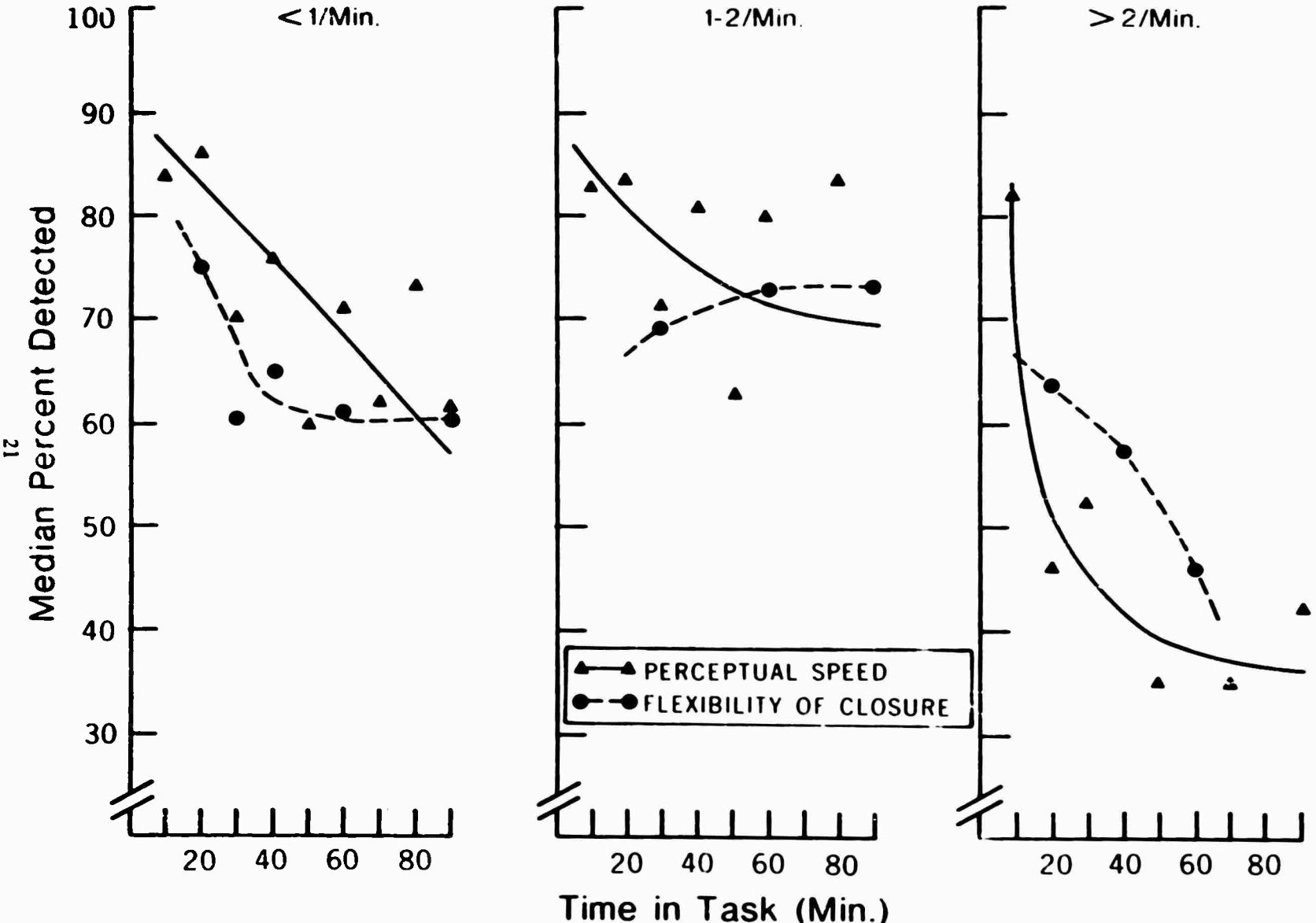

Figure 5. Median percent correct detections as a function of time in the task with signal rate and ability category as parameters

vigil and leveled off after the first hour. In addition, average performance accuracy on Flexibility of Closure tasks was lower than average performance accuracy on Perceptual Speed tasks.

For moderate signal rates, studies requiring Perceptual Speed for successful task performance demonstrated a gradual performance decrement with time in the task while studies in which Flexibility of Closure was required failed to show the typical vigilance decrement. The studies involving Flexibility of Closure showed a small degree of performance enhancement with time in the task, at least up to the first 90 minutes. Overall, performance for both the Flexibility of Closure and the Perceptual Speed categories at moderate signal rates indicated greater performance accuracy than the corresponding categories of studies for low signal rates.

At high signal rates, performance dropped very rapidly for tasks involving Perceptual Speed and showed little leveling off with time in the task. Similarly, the curve for Flexibility of Closure showed a very rapid drop in performance with time in the task. There appears to be little difference between the performance functions for Perceptual Speed tasks and Flexibility of Closure tasks when signal rates are high.

Figure 6 depicts percent correct detections at 30-minute intervals throughout the first 180 minutes of the vigil with sensory mode as the parameter. This independent variable was trichotomized into auditory, visual, and auditory-visual redundant categories. Smooth curves were fitted by eye to median performance levels for groups of studies falling into the Perceptual Speed and Flexibility of Closure categories. Regardless of the ability category, it appears that overall performance was superior under auditory conditions rather than visual conditions. Furthermore, the redundant condition was markedly superior to either auditory or visual presentation when the main ability required for task performance was Flexibility of Closure. Insufficient data were available to generate a function in the redundant condition for Perceptual Speed tasks.

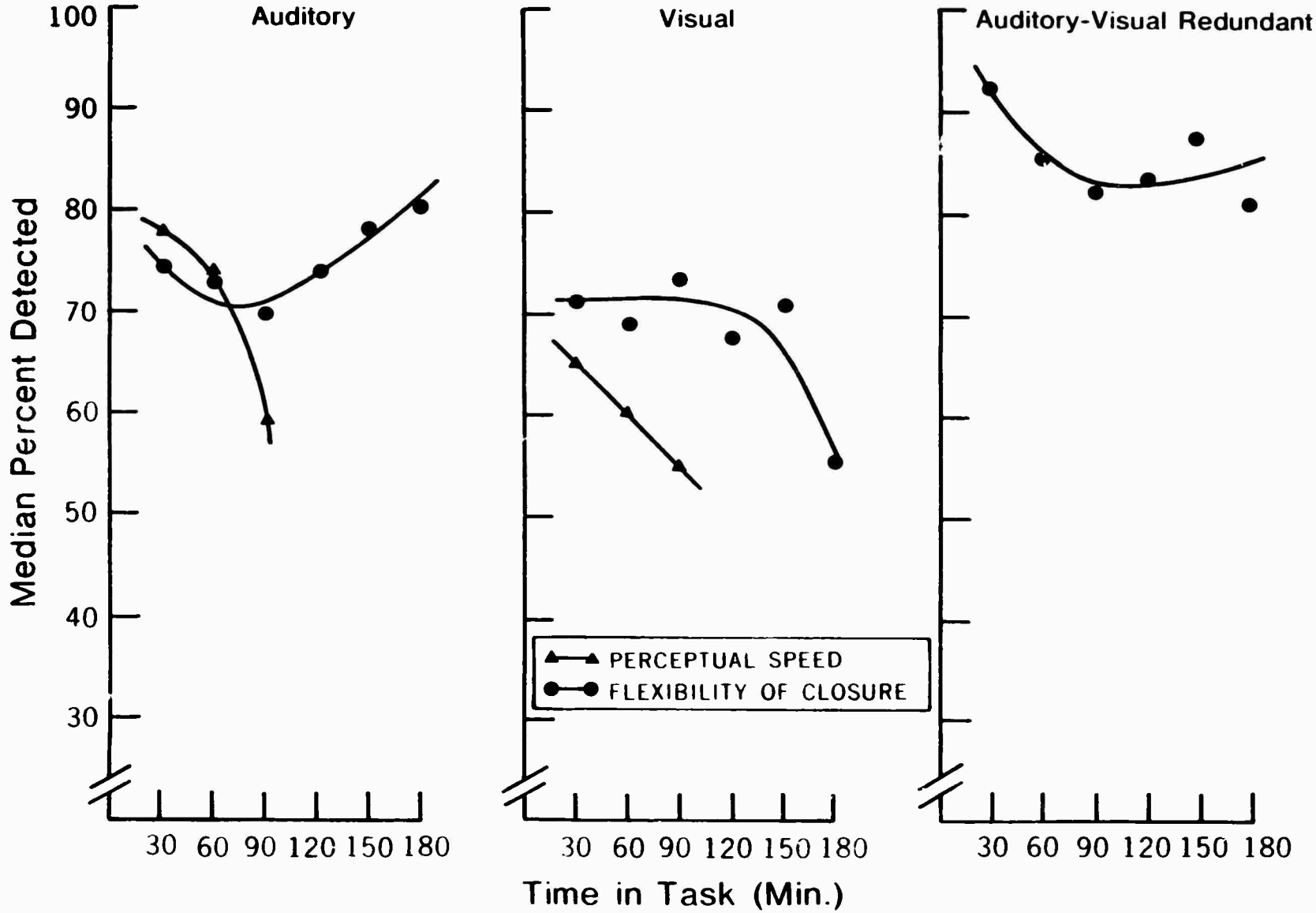

Figure 6. Median percent correct detections as a function of time in the task with sensory mode and ability category as parameters

Consideration of the auditory condition revealed a marked differentiation between the relationships describing performance as a function of time in the task for studies involving Perceptual Speed and those involving Flexibility of Closure. For Perceptual Speed tasks a severe performance decrement was obtained with time in the task, up to 90 minutes. Alternately, there was a very small performance decrement for Flexibility of Closure tasks within the first 90 minutes, and an increment in performance accuracy beyond that time. For the visual condition the function describing performance with time in the task for Perceptual Speed studies was very similar to that obtained for the auditory condition. However, the Flexibility of Closure function in the visual condition is almost the reverse of that for the auditory condition. That is, for studies in which Flexibility of Closure was the predominant ability, it appears that performance was constant during the first 90 minutes of the task, then a marked deterioration began to accrue.

While these data are preliminary and in several instances are based upon very few data points, it is nevertheless possible to infer that conclusions about performance in a vigilance task as a function of independent variables must be qualified in terms of the task requirements imposed upon the subjects. It has been demonstrated that when differential abilities are isolated, the relationships between performance and time in the task as a function of independent variables differ markedly.

Figure 7 shows medians computed across studies falling into either Perceptual Speed or Flexibility of Closure categories for knowledge of results and no knowledge of results conditions. Percent correct detections as a function of time in the task have been plotted and the points fitted by eye to generate a smooth function. Overall, the conclusion that knowledge of results is superior to no knowledge of results is, of course, supported. This can be seen by the fact that all of the data in the knowledge of results category reflect a higher percentage of correct detections than the data in the no knowledge of results category. The

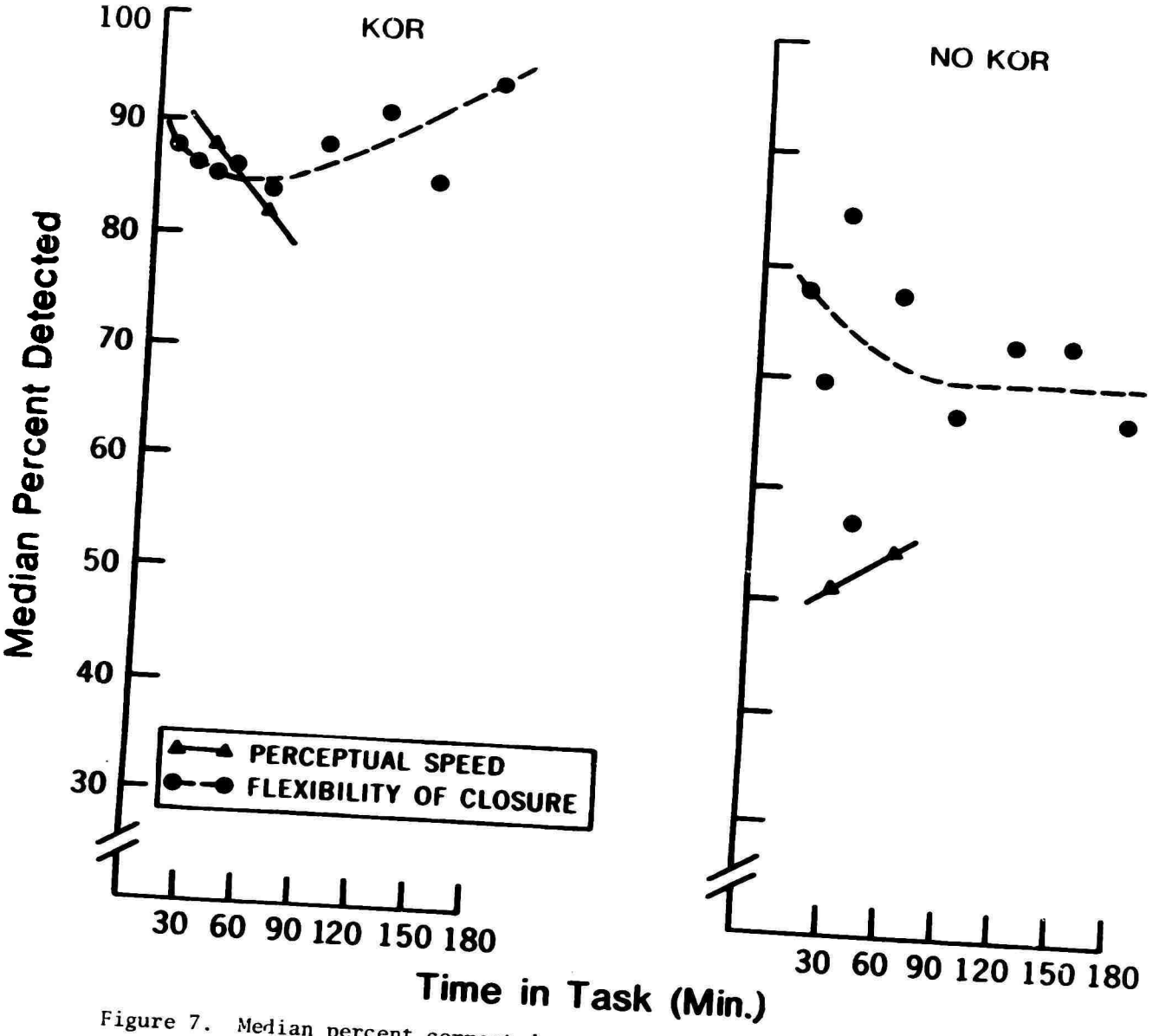

Figure 7. Median percent correct detections as a function of time in the task with knowledge of results conditions and ability category as parameters

number of data points available for establishing the functional relationship between percent detection and the time in the task for Perceptual Speed tasks was extremely small and, therefore, does not warrant any interpretation. Sufficient data, however, were available to establish a function for Flexibility of Closure in both the knowledge of results and no knowledge of results conditions. When knowledge of results was provided, there was a very small initial decrement in performance followed by a leveling off and subsequent improvement in performance accuracy. In the no knowledge of results condition, on the other hand, the performance decrement was moderate and consistent through the first 90 minutes of the vigil, after which no further decrement occurred.

Here, as earlier when signal rate and sensory mode were discussed, a fine-grained analysis of performance in terms of the ability requirements of the task has allowed conclusions to be drawn and inferences to be made which were not otherwise possible. That is, the categorization of results in terms of the predominant abilities required for task performance has clearly shown different relationships between performance and time in the vigil as a function of levels of an independent variable which would not have been apparent without this additional categorization.

Classifications by Multiple Abilities and Stringent Criteria

Performance functions for studies requiring either Perceptual Speed or Flexibility of Closure were fitted to medians by eye and describe percent correct detections at 10-minute intervals for the first 90 minutes of the vigil. These data are presented in Figure 8. A stringent criterion for accepting studies into either the Perceptual Speed or Flexibility of Closure categories was adopted. Not only did the tasks have to require Perceptual Speed or Flexibility of Closure as the predominant ability, but this predominant ability had to be "significantly" more important than any other ability which also may have been required for the task. Specifically, the criterion was that the predominant ability be rated at least a "5" and be two scale points higher than the

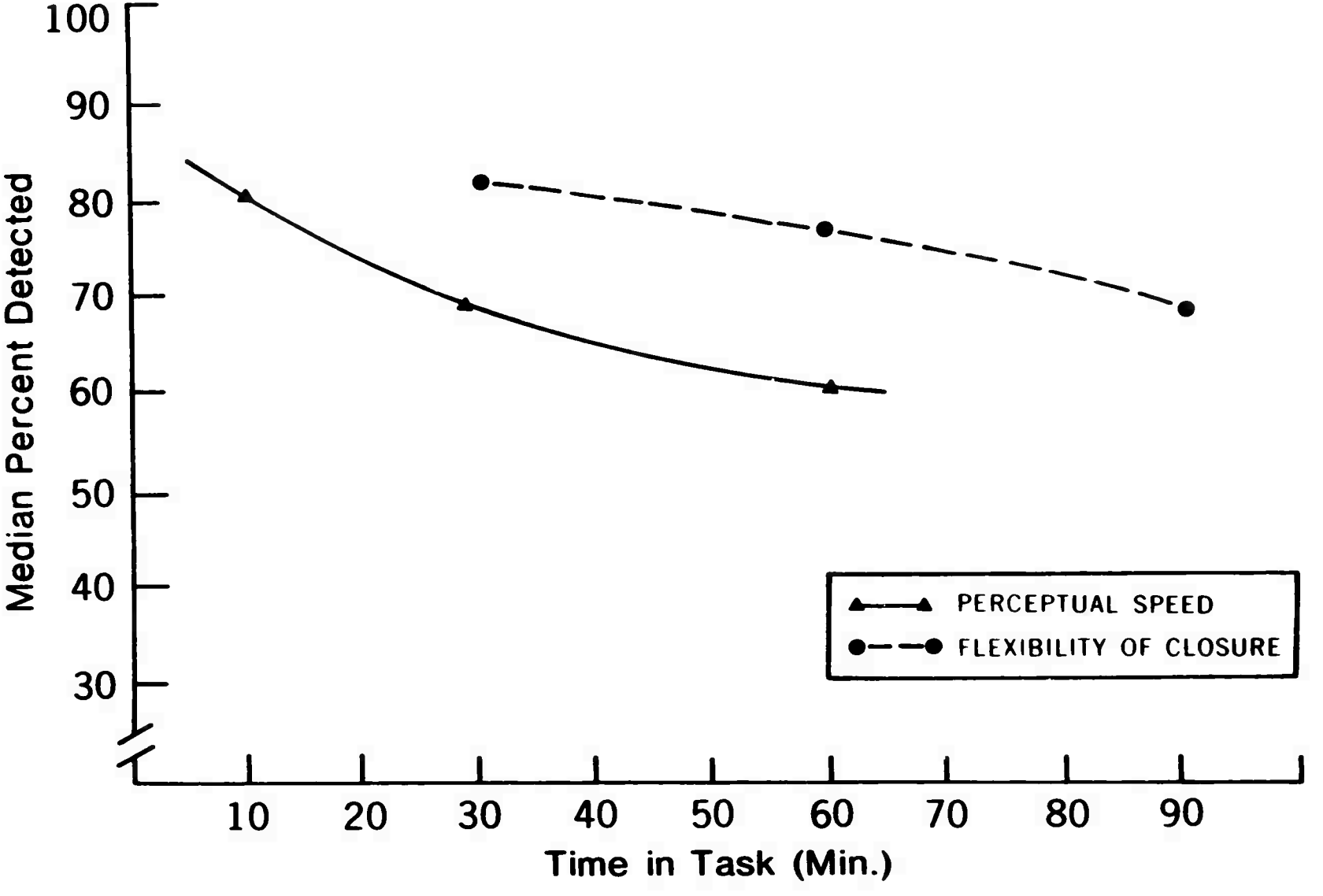

Figure 8. Median percent correct detections as a function of time in the task with ability category as the parameter

next highest rated ability. Such a stringent criterion was adopted in order to evaluate the nature of performance in those few tasks where either Perceptual Speed or Flexibility of Closure was by far the most predominant ability and substantially superseded any other ability requirement.

Performance for Perceptual Speed tasks deteriorated with time in the task up to 60 minutes. However, the degree of deterioration decreased with time in the task. The function is the standard one found for vigilance performance. A different functional relationship was found for tasks which emphasized Flexibility of Closure. While performance accuracy decreased with time in the task through the first 90 minutes, the rate of deterioration increased with time rather than decreased. For both functions, performance accuracy at the start of the vigil was approximately the same, i.e., 80%. One hour into the vigil, performance accuracy for Perceptual Speed tasks decreased to about 60% while that for Flexibility of Closure tasks fell to about 75%.

When the functions in Figure 8 are compared with their companion functions in Figures 1 and 2, the relationships between accuracy and time in the task for Perceptual Speed studies were practically identical, while those for Flexibility of Closure studies were different. The application of the more stringent criterion for study acceptance altered the functional relationship between accuracy and time in the task for studies involving Flexibility of Closure. Figure 2, describing the functional relationship when the non-stringent criterion was applied, showed a slow decrement in performance up to the first hour, followed by an enhancement of performance during the next 30 minutes of the vigil. On the other hand, an increased decrement in performance was noted with further time in the vigil when the more stringent criterion was applied (Figure 8). The equivalent functions for Perceptual Speed in Figures 1 and 8 show a continuous performance decrement at least through the first hour of the vigil. These comparisons within and between ability categories provide some evidence for differential discrimination of

relationships between performance and time in the vigil according to the precise nature of the abilities involved in task performance.

Figure 9 depicts three functions, each describing performance accuracy with time in the vigil for studies classified in terms of both a predominant and secondary ability. A secondary ability was defined as one which was rated second highest relative to the predominant ability. Two of the functions relating performance to time in the task denote the predominant ability of Perceptual Speed and a secondary ability of either Attention or Time Sharing. These functions, based upon medians for all studies falling into these two classifications, are different. When Time Sharing was the second most important ability, the rate of performance deterioration over time was markedly greater than it was when Attention was the second most important ability. In addition, for the Perceptual Speed-Time Sharing combination, performance linearly decreased as a function of time in the task, while for the Perceptual Speed-Attention grouping, the function describing performance with time in the task leveled off at approximately 90 minutes into the vigil. The third function in Figure 9 shows the relationship between performance and time in the vigil when Flexibility of Closure was the predominant ability and Attention was the second most important ability. This function indicates that performance deteriorated up to the first hour in the task, then improved with additional time in the task. This function might be compared to the one in which Attention was also the second most important ability, but Perceptual Speed was the predominant ability. In the latter function, performance leveled off after 90 minutes.

Overall, these data seem to suggest that not only will classification of research findings according to predominant abilities required by the task lead to differential inferences with regard to the impact of independent variables upon performance, but also that the pattern of ability requirements for the task will lead to such differential inferences. It seems that it is important to consider the predominant ability and the nature of the secondary ability and perhaps the nature of other abilities for task performance in order to generalize research findings.

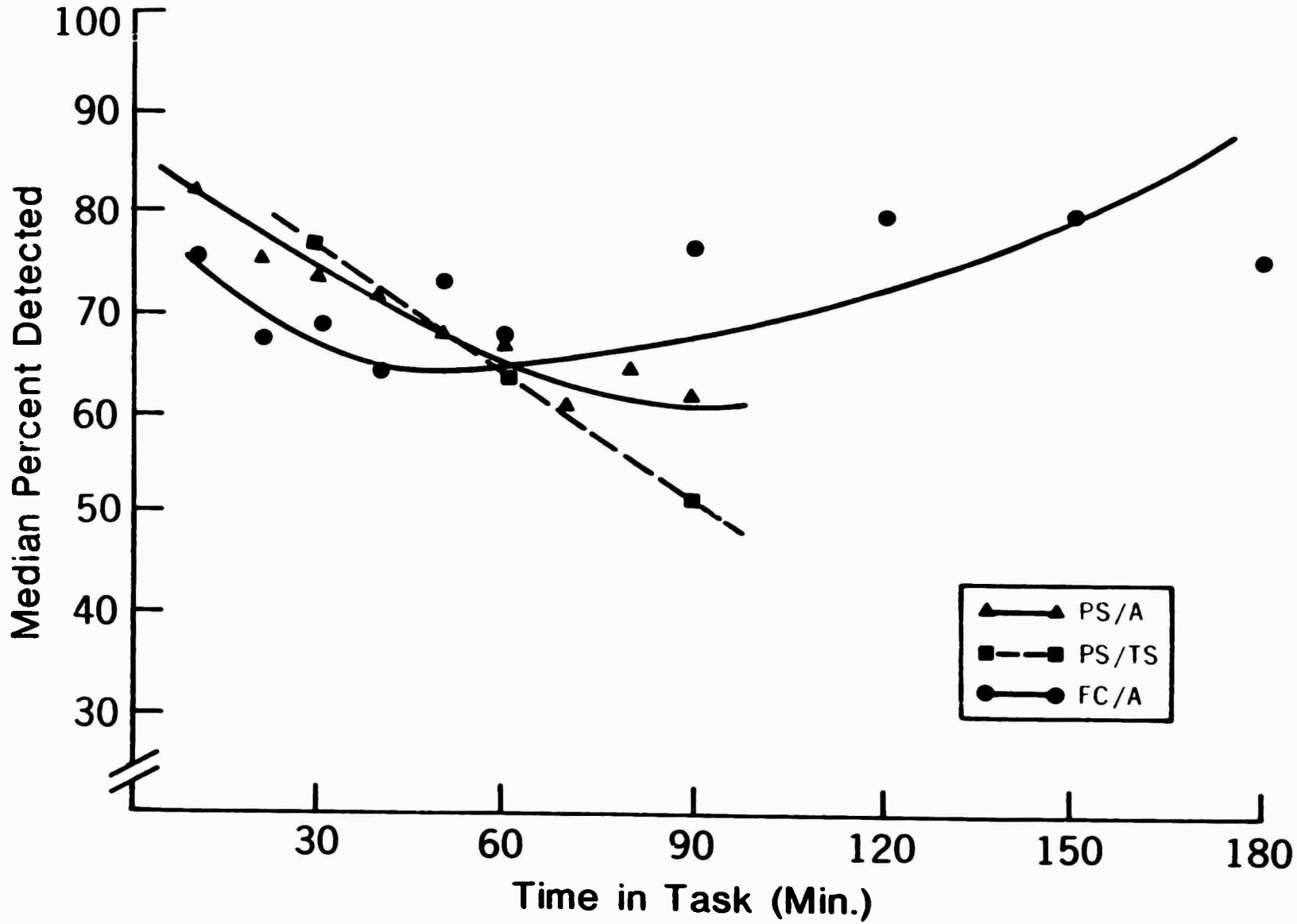

Figure 9. Median percent correct detections as a function of time in the task with primary and secondary ability requirements as the parameter

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This study was conducted to provide a preliminary evaluation of an abilities approach to the organization of an area of experimental literature. Vigilance, the area chosen, is rather precisely defined in terms of characteristics of the task situation and contains homogeneous tasks. It is this homogeneity which could lead one to anticipate little differentiation of task performance by categories of ability requirements. However, classifying tasks according to a small set of abilities did result in markedly different performance functions over time.

Performance, measured in terms of percent of signals correctly identified, typically decreases as a function of time in the vigil. Although this finding has been repeatedly demonstrated in the vigilance literature, no one had previously indicated whether the nature of this function differs for different tasks. By classifying tasks according to one of four primary abilities required for task performance, differential relationships between performance and time in the vigil were obtained. The most notable difference among the functions was that performance deteriorated up to a certain point in time, then became enhanced when vigilance tasks required the abilities of Flexibility of Closure, Attention, or Time Sharing, but for tasks which required Perceptual Speed, the performance decrement did not reverse.

In the present study, when task performance was partitioned by levels of three independent variables (signal rate, sensory mode and KOR) marked differences in the functional relationships emerged for the two primary ability categories of Perceptual Speed and Flexibility of Closure. The impact of an independent variable on performance was a function of the abilities required by the tasks.

Where sufficient data were available to generate functions for the Perceptual Speed and Flexibility of Closure categories, differences in functional relationships were found at each level of each independent

variable, with the exception of the high signal rate condition. Functional relationships between performance and time in the vigil for Perceptual Speed tasks and Flexibility of Closure tasks were different both within and between low and moderate levels of signal rate. At low levels, tasks requiring the predominant ability of Flexibility of Closure demonstrated a sharp decrement in performance accuracy early in the vigil followed by a leveling off, while Perceptual Speed tasks showed a linear decrease in performance with time in the vigil. At moderate rates, Perceptual Speed tasks showed a gradual performance decrement over time, whereas tasks involving Flexibility of Closure showed no such decrement, but a slight enhancement in performance.

When signals were presented auditorily, performance in Perceptual Speed tasks declined quickly with time in the task while performance in Flexibility of Closure tasks deteriorated slightly, then improved with time. In the visual situation, Perceptual Speed tasks showed a similar rapid performance decrement while a near reversal in performance was indicated for Flexibility of Closure tasks; that is, performance remained constant, then rapidly deteriorated. For auditory-visual redundant presentation of signals, tasks requiring Flexibility of Closure showed a decline in performance, then a tendency toward improved performance. In general, dual mode presentation of signals was superior to either of the single mode presentations, i.e., auditory or visual.

In the case of the knowledge of results variable, too little data were available for Perceptual Speed tasks to merit evaluation. However, for tasks requiring Flexibility of Closure, provision of knowledge of results tended to enhance performance after a slight initial drop, while no feedback resulted in a decrement in performance followed by maintained accuracy with time in the task.

Each of the three independent variables were selected because of their known, generally consistent effects on performance in vigilance tasks. For sensory mode and knowledge of results the anticipated overall relationships were obtained. A departure from the expectation that

performance is enhanced with increased signal rates was noted in the current study for both Perceptual Speed and Flexibility of Closure tasks. While performance was generally better when one-to-two signals per minute were presented than when less than one signal per minute was presented, performance deteriorated to a much lower level than in either of these conditions when more than two signals per minute were presented. The general finding of enhanced performance with increased signal rates was supported only up to signal rates of two per minute. The lower performance levels indicated for the highest signal rates were unexpected.

Tasks were classified not only by the primary ability required for performance, but were also classified jointly in terms of a primary and secondary ability. Functional relationships developed according to primary ability categories were somewhat modified by consideration of a secondary ability in conjunction with the primary one. This finding implies that consideration of multiple abilities required for performance of a task might alter the functional relationships developed strictly on the basis of a single predominant ability. The question is an empirical one to be answered through future research.

It should be emphasized that despite the differences among specific tasks in terms of equipment, displays, response requirements, etc., our classification system enabled an integration of results and the development of functional relationships that were otherwise obscured.

Overall, the abilities approach to the classification of vigilance tasks yielded different functional relationships between performance and time in the vigil when tasks were categorized according to the primary ability required for task performance. Furthermore, the impact of an independent variable on vigilance performance was a function of the abilities required for task performance. These findings demonstrate the feasibility and utility of the ability approach as a classification tool to integrate and generalize research findings. The application of this approach to a broader, more heterogeneous content area using a wider range of ability categories seems warranted to determine whether similar results could be obtained.

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APPENDICES

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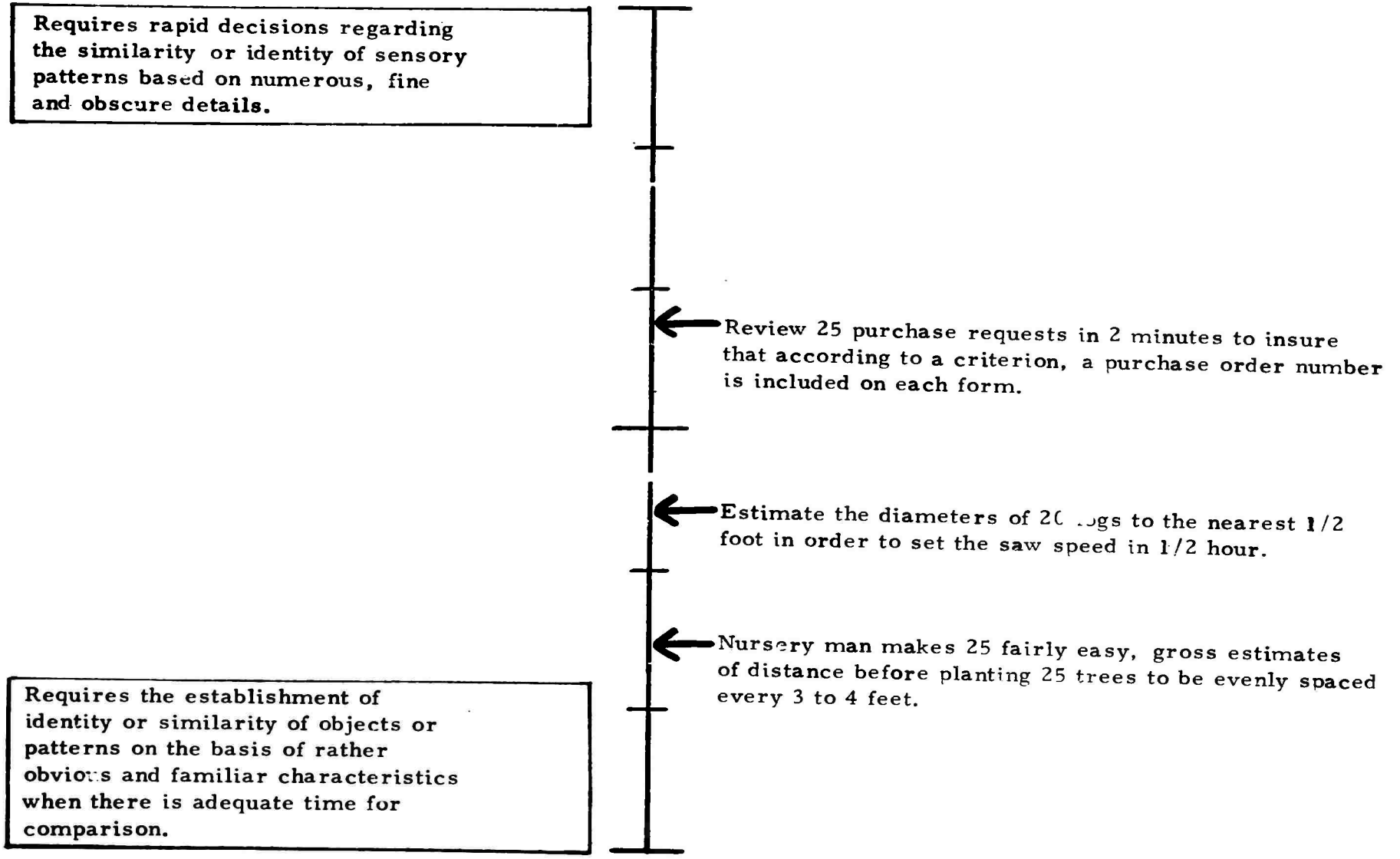
APPENDIX I

FOUR ABILITY CATEGORIES FROM THE TASK ASSESSMENT SCALES REFERENCE MANUAL

PERCEPTUAL SPEED

This ability involves the speed with which sensory patterns or configurations can be compared in order to determine identity or degree of similarity. Comparisons may be made either between successively or simultaneously presented patterns or configurations, or between remembered or standard configurations and presented configurations. The sensory patterns to be compared must occur within the same sense and not between senses.

PERCEPTUAL SPEED



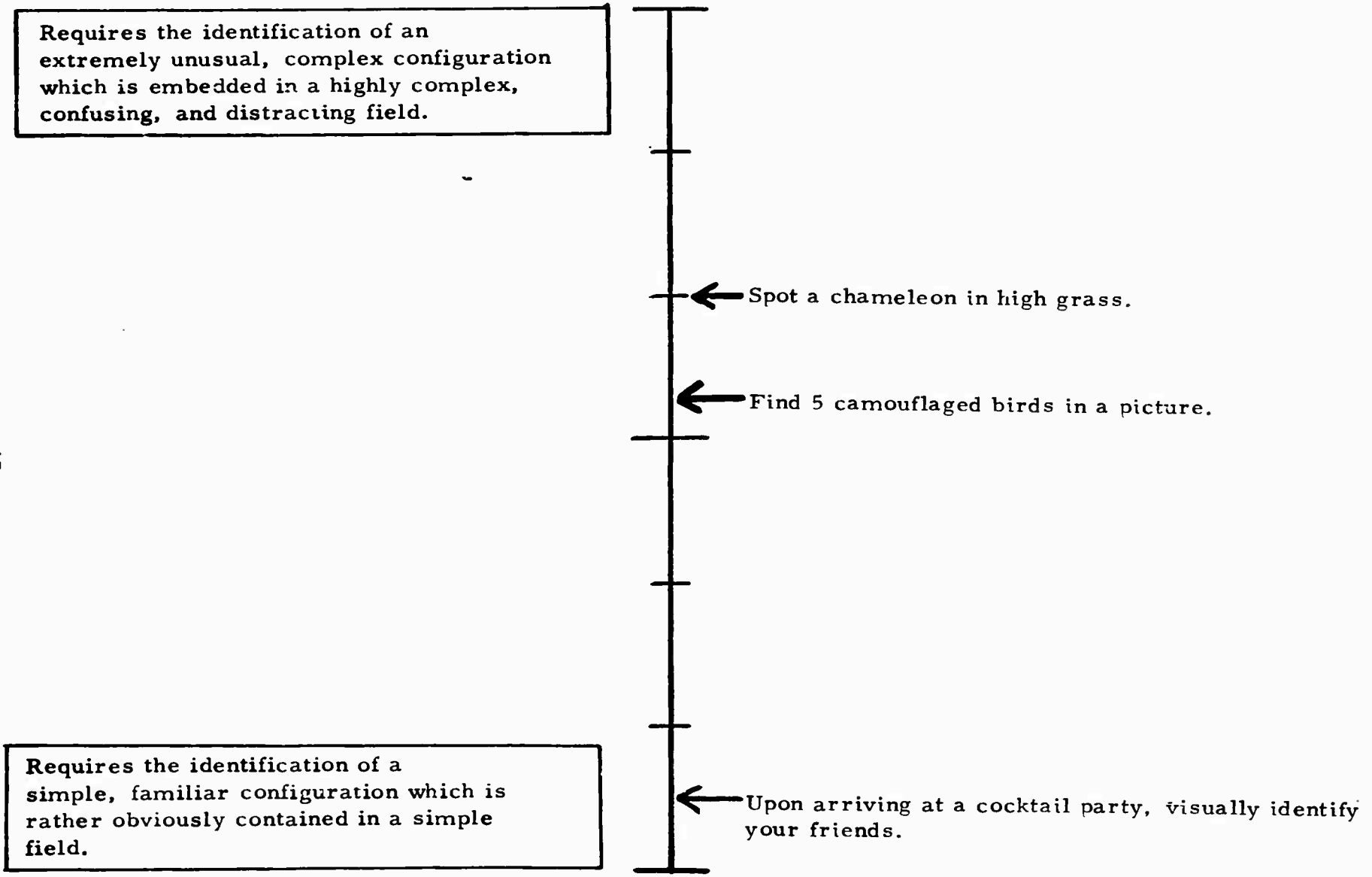
FLEXIBILITY OF CLOSURE

This is the ability to identify or detect a previously specified stimulus configuration which is embedded in a more complex sensory field. It is the ability to isolate the specified relevant stimulus from a field where distracting stimulation is intentionally included as part of the task to be performed. Only one information source is utilized. This ability applies to all senses with the restriction that both the relevant and distracting stimulation must occur within the same sense modality.

FLEXIBILITY OF CLOSURE DISTINGUISHED FROM OTHER ABILITIES:

Operator tries to identify a specified configuration.	vs.	Speed of Closure (15): Operator is not told what he is trying to identify.
Distracting stimulation is included in the task to be performed; i.e., it is an integral part of the task.	vs.	Attention (17): Distracting stimulation is not included in the task to be performed; i.e., it is external to the task.
Only one source of information is utilized.	vs.	Time Sharing (18): More than one source of information is utilized.

FLEXIBILITY OF CLOSURE



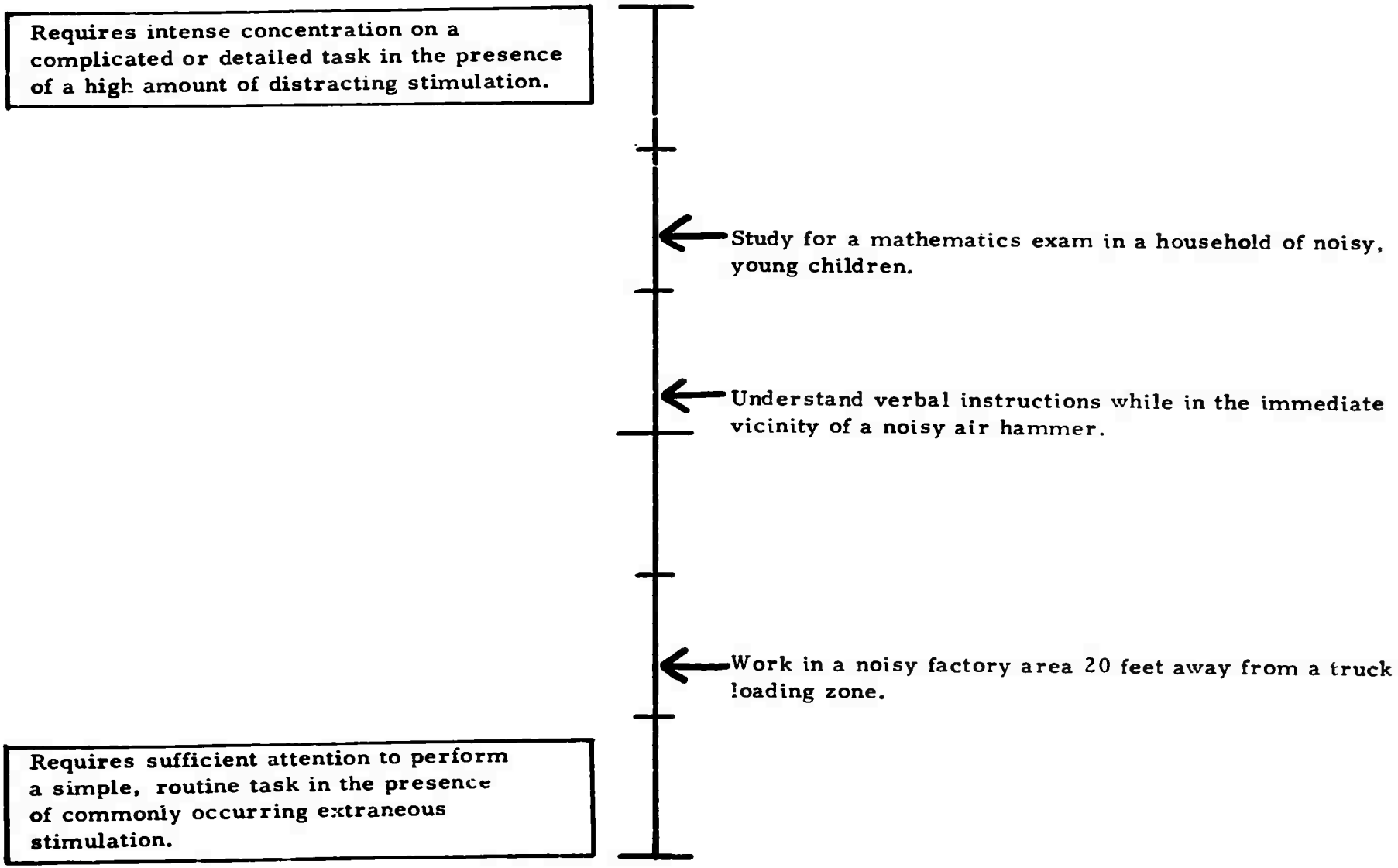
SELECTIVE ATTENTION

This is the ability to perform a task in the presence of distracting stimulation or under monotonous conditions without significant loss in efficiency. When distracting stimulation is present in the task situation, it is not an integral part of the task being performed, but rather is extraneous to the task and imposed upon it. The task and the irrelevant stimulation can occur either within the same sense or across senses. Under conditions of distracting stimulation, the ability involves concentration on the task being performed and filtering out of the distracting stimulation. When the task is performed under monotonous conditions only concentration on the task being performed is involved.

SELECTIVE ATTENTION DISTINGUISHED FROM OTHER ABILITIES:

Some of the stimuli are not relevant to the task.	vs.	Speed of Closure (15): All of the stimuli are relevant to the task.
Distracting stimulation is not included in the task to be performed; i.e., it is external to the task.	vs.	Flexibility of Closure (16): Distracting stimulation is included in the task to be performed, it is an integral part of the task.
Concentration on relevant information and filtering out distracting stimulation.	vs.	Time Sharing (18): Involves utilization or integration of information obtained from two or more sources.

SELECTIVE ATTENTION



TIME SHARING

This is the ability to utilize information obtained by shifting between two or more channels of information. The information obtained from these sources is either integrated and used as a whole or retained and used separately.

TIME SHARING DISTINGUISHED FROM OTHER ABILITIES:

More than one source of information is utilized.	vs.	Speed of Closure (15) and Flexibility of Closure (16); Only one source of information is utilized.
Utilization or integration of information from more than one source.	vs.	Selective Attention (17): Concentration on relevant information and filtering out of distracting stimulation.

TIME SHARING

Requires the simultaneous use of two or more channels of complex information where the rate of information input in each channel is rapid.

← Air traffic controller monitors radar scope to keep track of inbound and outbound planes during a period of heavy, congested traffic.

← Playground director supervises 50 children who are engaging in many different activities.

← Short stop watches the lead of the runner on second and actions of the pitcher.

Requires the utilization of two channels of rather simple information where the operator can shift sequentially between channels in which the rate of information input is low.

APPENDIX II

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APPENDIX III

LITERATURE ABSTRACTING FORM

Literature Abstracting Form

1. Complete Reference

2. Independent Variables

	Name	# Levels	Specification of Levels
(a)			
(b)			
(c)			
(d)	Trials		

3. Performance Measures

	Name	Operational Definition
(a)		
(b)		
(c)		

4. Index of Vigil (time course data every K minutes/hours)

5. Abilities Involved

	Ability	Code #	Domain	Degree	Rank
(a)					
(b)					
(c)					
(d)					
(e)					

6. Task Description Details

7. Report Abstract (from author's summary)

8. Data (For each performance index, record the means at every combination of experimental conditions given in the document. Also list statistically reliable effects.)

Effects Listing

Source	Significance	Specific Comparison

Performance Matrix

AMERICAN INSTITUTES FOR RESEARCH

Research Offices

ASIA/PACIFIC
Bangkok, Thailand
APO San Francisco 96346

KENSINGTON
10605 Concord Street
Kensington, Maryland 20795

PALO ALTO
P.O. Box 1113
Palo Alto, California 94302

PITTSBURGH
710 Chatham Center Office Building
Pittsburgh, Pennsylvania 15219

WASHINGTON
8555 Sixteenth Street
Silver Spring, Maryland 20910

Corporate Offices

PALO ALTO
P.O. Box 1113
Palo Alto, California 94302

PITTSBURGH
710 Chatham Center Office Building
Pittsburgh, Pennsylvania 15219

WASHINGTON
1775 K Street, N.W.
Washington, D.C. 20006