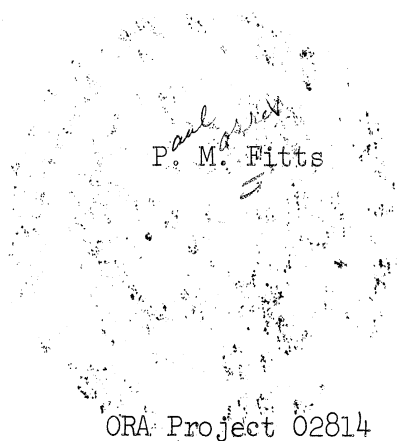


THE UNIVERSITY OF MICHIGAN
COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS
Department of Psychology

Final Report

INFORMATION-HANDLING AND DECISION-MAKING BY INDIVIDUALS AND SMALL TEAMS



under contract with:

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
OFFICE OF AEROSPACE RESEARCH
CONTRACT NO. AF 49(638)-449
WASHINGTON, D.C.

administered through:

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OBJECTIVES OF THE RESEARCH PROGRAM

The purpose of the research program under Contract No. AF 49(638)-449, which was initiated in September, 1958, was to analyze the performance of individuals working singly and in small teams in a variety of information-processing tasks, including not only information-transmission tasks but also tasks in which they would have to learn to deal with probabilistic information, to categorize and filter information, to utilize feedback from previous responses, and to apply rules or concepts in dynamic choice or decision situations. An information-theoretic approach was followed in all of this work, but emphasis was upon aspects of behavior in which the individual could adapt in various ways to the special demands of the task. Emphasis was also focused on rate of performance in all of the research. Team performance was considered as an extension of individual performance, with varying information-exchange processes between team members and a well-defined output criterion.

SOME HIGHLIGHTS OF THE RESEARCH FINDINGS

Research findings from this program have been published in professional journals, theses, and special technical reports, and reported at various scientific meetings. Therefore, no attempt will be made here to review or summarize all of the results of the research. However, a few highlights can be singled out for emphasis and by way of summary of the results.

AN INFORMATIONAL APPROACH TO THINKING

Nearly all previous studies of human capacity in information-processing tasks have employed information-conserving tasks, in which all of the stimulus (input) information must be preserved in the responses (output). Under the present research program considerable progress was made in the analysis of performance in tasks ordinarily considered to involve thinking or higher-level cognitive processes. Information reduction is one broad class of such tasks. The individual must select relevant information (filtering) or must categorize information into fewer classes than there are stimuli after consideration of all stimulus characteristics (condensing). Some outstanding contributions to the understanding of information-reduction processes were made by Dr. Michael Posner in his Ph.D. thesis, "An Informational Approach to Thinking" (ORA No. 02814-9-T), which received the Marquis Award of the Department of Psychology at The University of Michigan for the best thesis in Psychology in 1961, and also won first place in nationwide competition for the American Institute of Research Creative Talent Award for the best thesis in experimental psychology. One of the principal findings from this research was that given some specified information source, the greater the degree of information condensing required (the smaller the output information) the more time required for the information processing by human subjects. In terms of response information, this is just the opposite relation to that which holds for information-conserving tasks.

COGNITIVE ASPECTS OF INFORMATION PROCESSING

A series of numbered reports in the Journal of Experimental Psychology bearing this main title have been published, and a paper with this title was presented and is being published as part of the proceedings of the XVII International Congress of Psychology, which was held in Washington in August, 1963. These reports have analyzed the important role of processes such as cognitive set (familiarity with sets of alternatives, adjustments for speed vs. accuracy, etc.) in human-information processing. Thus an individual is viewed as using many adaptive processes which permit him to handle different information-processing tasks in different ways and the research contributes to an understanding of man's versatility.

SPEED-ACCURACY RELATIONS

It has long been known that man has great capacity for achieving accuracy (reliability, precision, etc.) at the expense of speed and vice versa. A decision-theoretic model has now been proposed to account for how this trade-off is accomplished. It treats perception, discrimination, and information processing as involving rapid sequential stimulus sampling. Results of studies using this approach have been reported and show considerable promise especially in accounting for man's capacities in dealing with redundant sequences. These findings emphasize that errorless performance is a questionable concept; some risk of error must be accepted in any task accomplished under time stress, although it may be possible to make error rate arbitrarily small. Such a theory has great significance for application to military reliability work.

HIERARCHICAL AND TEMPORAL ASPECTS OF INFORMATION-PROCESSING SKILLS

The view has long been held that skills are organized hierarchically, both in terms of sequences of actions, and levels of organization. However, little recent evidence has been advanced on this issue, especially as regards information-processing skills. In several recent studies accomplished under the present research program, including Dr. Richard Pew's Ph.D. thesis, "Temporal Organization in Skilled Performance" (ORA No. O2814-11-T), analytic data have been obtained which shed new light on the role of hierarchical processes in skills. In terms of temporal organization, individuals were shown to organize short patterns of motor behavior, lasting for up to one half second or more, in advance of initiating the response sequence. Dr. Pew was able to demonstrate two processes in a control task, a continuous rapid control process (up to six or eight responses per second), which was modulated by a slower, higher-level regulatory process. In other studies it has been demonstrated that perceptual or decision time, and movement execution time, are quite independent processes. Various stages in skill learning have been proposed and detailed expositions published as chapters in two separate books on learning and training. In essence it is hypothesized that individuals develop semi-automatic habits, or subroutines, that run off essentially as "open-loop" processes, but which in turn are governed by slower and intermittent cognitive processes that can be viewed as analogous to executive programs.

USE OF HEURISTIC PROCEDURES IN PROBLEM SOLVING

Several studies were completed that extend information-theoretic concepts to tasks in which subjects are asked to find solutions to problems for which no algorithm (procedure for guaranteeing an optimum solution) is available. Typical tasks included the transportation-assignment and the personnel-assignment problems. Individual performance was found to be surprisingly good on such problems, from the outset of training, in comparison with solutions produced by a random process, by reliance on simple heuristic rules, and by

optimizing procedures; however, learning was very slow and subjects were not able to give exact descriptions of the methods they employed in finding solutions. The time required to find acceptable solutions was found to be highly correlated with the total number of possible solutions and the average information reduction per step in the solution (thus agreeing with findings in studies of information condensing).

INFORMATION SHARING FOR TEAM PERFORMANCE

Studies relating to the display of information, and the organization of information exchange procedures for efficient team performance in information processing and decision making, have suggested two main concepts. First, under conditions of high-information load and time stress, increased information exchange (communication) processes between team members usually slows up team performance; thus in a sense communication processes compete for limited human channel capacity. Second, team performance may be considerably enhanced by the use of visual information exchange devices, i.e., by the provision of information sharing via visual rather than via auditory channels. One reason which is believed to account for this effect is that visual information exchange can thus be scheduled on an individual basis, to take advantage of momentary light periods of work load, without interrupting the work of two people at inopportune times.

PUBLICATIONS

The following is a list of reports of the work supported by this contract, which have been published in books and professional journals, or as Ph.D. theses, and which are now available to scientists or are in press and will be available during the current year.

BOOKS AND JOURNAL ARTICLES

Fitts, P. M. and Switzer, Gail. Cognitive Aspects of Information Processing I: The Familiarity of S-R Sets and Subsets. J. Exp. Psychol., 1962, 63, 321-329.

Fitts, P. M., Peterson, J. R., and Wolpe, G. Cognitive Aspects of Information Processing II: Adjustments to Stimulus Redundance. J. Exp. Psychol., 1963, 65, 507-514.

Fitts, P. M. and Peterson, J. R. The Information Capacity of Discrete Motor Responses. J. Exp. Psychol., 1964 (in press).

Fitts, P. M. and Biederman, I. S-R Compatibility and Information Reduction (submitted to Journal of Experimental Psychology).

Fitts, P. M. Skill Learning. Chap. in A. W. Melton (Editor), Categories of Human Learning, Academic Press, 1964.

Fitts, P. M. Contribution to the Consideration of Information Processing and the Nervous System. Proceedings, International Congress of Physiological Sciences, Lieden, Holland, Sept., 1962 (Excerptia Medica, in press).

Fitts, P. M. Cognitive Aspects of Information Processing. Proceedings of the XVII International Congress of Psychology, Washington, D.C., Aug., 1963, North-Holland Publishing Co. (in press).

Fitts, P. M. Factors in Complex Skill Training. Chap. 6 in R. Glaser (Editor) Training Research and Education, Pittsburgh, U.Pitt. Press, 1962.

It is expected that several additional reports, based in part on work initiated under this contract will be published subsequently with joint credit to the present contract and to a subsequent AFOSR contract (No. AF 49(638)-1235).

PH.D. THESES

The following Ph.D. theses were completed during the period of this contract:

Moore, H. G. The Effects of Load and Accessibility of Information Upon Performance of Small Teams. Ph.D. Thesis and AFOSR Report No. 1636, October, 1961.

Posner, Michael I. "An Informational Approach to Thinking," Ph.D. Thesis and AFOSR Report No. 2635, April, 1962.

Stimmel, Theron. Problem Solving Requiring the Use of Heuristic Procedures. Ph.D. Thesis, September, 1962.

Pew, Richard. Temporal Organization in Skilled Performance. Ph.D. Thesis and Report No. 02814-11-T, May, 1963.

EDUCATIONAL TELEVISION

Two 30-minute Educational Television Films were completed during the period of this contract and have been shown widely on the National Educational Television network. These films were not supported by the contract, but they do report aspects of the work accomplished under this contract. The first film was produced (and supported financially) by The University of Michigan and deals exclusively with work supported by this contract; the second was produced by the American Psychological Association, with funds provided by the National Science Foundation, and covers work at Wright Air Development Division and elsewhere as well as some of the findings of the present program. The titles of these educational films are:

"The Stitch in Time." University of Michigan Television Center, Series, Of Men and Motives, File No. 11D.

"Of Men and Machines." National Educational Television and Radio Center, Ann Arbor, Michigan. (P-59-9; Series, Focus on Behavior)

PERSONNEL

The following persons served on the staff for some period of time during the work on this contract:

PROFESSIONAL STAFF

Dr. Paul M. Fitts (Project Supervisor)
Dr. Roy Davis (Visiting Scientist from Oxford University)
Dr. Robert Isaacson (Psychologist)
Dr. Wilfred Kincaid (Consultant in Mathematics)

GRADUATE STUDENTS (ASSISTANTS IN RESEARCH)

Biederman, Irving	Pickett, Ronald
Brown, Betty	Smith, Edward
Henry, G. Croft	Switzer, Gail
Kibler, Austin (Major, USAF)	Smith, Robert L.
Moore, Heber G.	Stimmel, David T.
Passini, Frank	Tomlinson, Percival
Pew, Richard	Von Buseck, Calvin
Peterson, James R.	Wolpe, Gerson

RESEARCH ASSISTANTS OTHER THAN GRADUATE STUDENTS

Levine, Peter	Roberts, Kelyn
Mylrea, Kenneth	Rosthal, Marianne
Radford, Barbara	Story, Vern
Tobin, Paula	

It is estimated that approximately 900 University of Michigan students served as subjects in experiments under this program.

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