Technical Report 435

LEVEL II

AN ANNOTATED SELECTIVE BIBLIOGRAPHY ON HUMAN PERFORMANCE IN FAULT DIAGNOSIS TASKS

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This is an annotated bibliography of 61 published works about human performance in fault diagnosis. The sources are predominatly from the disciplines of engineering, psychology and education. Computer searches were conducted of the past 10 years of Psychological Abstracts and ERIC Documents. Manual searches using references from reports, University of Illinois library card catalog, and solicitation of references from experts in the field extended the search to include references dating from the early fifties.

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FOREWORD

The Manpower & Educational Systems Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas that include educational technology and training simulation with applicability to military training. Of special interest is research in the area of computer-based systems for maintenance training. The development and implementation of such systems is seen as a means of reducing training time and costs by providing more highly individualized training than would be otherwise possible, while at the same time reducing the need for operational equipment for training.

The report provides an annotated bibliography of research directly related to human problem-solving behavior in fault diagnosis (trouble-shooting) tasks. It provides an information source to assist planners of future research efforts in this area.

This research is responsive to the requirements of RDT&E Project 2Q161102B74F, "Basic Research in the Behavioral and Social Sciences."

JOSEPH ZEIDNER
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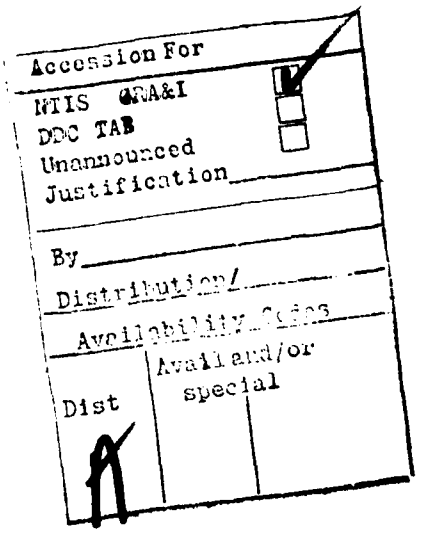

AN ANNOTATED SELECTIVE BIBLIOGRAPHY ON HUMAN PERFORMANCE IN FAULT DIAGNOSIS TASKS

BRIEF

Requirement:

In conjunction with an ongoing program of research on the use of computer simulations for fault diagnosis training, a thorough review of the existing literature was necessary to provide historical input and to identify current trends in fault diagnosis work. The results of this search are presented here as a selective annotated bibliography.

Procedure:

The search procedure consisted of on-line computer search of the past 10 years of Psychological Abstracts and ERIC Documents through mid-1978. Manual searches used references from reports as well as from the card catalog of the University of Illinois library. In addition, experts in the area of fault diagnosis were sent the references resulting from the computer and manual searches and asked to suggest any additional references that should be included.

Findings:

The references revealed by the search procedure were predominately from the areas of engineering, psychology, and education. Three major categories of materials are presented. These consist of (1) research reports, (2) manuals for fault diagnosis, and (3) material indirectly related to fault diagnosis, such as medical diagnosis and mathematical problem solving, or items directly related to fault diagnosis that are not research reports.

Utilization of Findings:

This annotated bibliography will serve as an information source for planners of future R&D efforts in this area.

INTRODUCTION

The authors and several colleagues at the University of Illinois are investigating the use of computer simulations for fault diagnosis training. This work runs the gamut from context-free simulations and context-specific simulations into the live environment of real equipment troubleshooting. This research, supported by the U.S. Army Research Institute for the Behavioral and Social Sciences, includes the development of models of human fault diagnosis performance and ultimately an intelligent interactive training simulator. To this end, we have already run six experiments involving almost 160 subjects who solved approximately 13,000 fault diagnosis problems.

As part of our work, we have prepared this annotated selected bibliography on human performance in fault diagnosis tasks. The sources in this bibliography are predominantly from the disciplines of engineering, psychology, and education. Although the primary emphasis is on the research literature, we have included a representative number of actual troubleshooting manuals from the automotive and aviation fields.

The literature search included several phases, involving both on-line and manual searches. Computer searches of the past ten years of Psychological Abstracts and ERIC documents through mid-1978 were performed. Manual searches were conducted using bibliographies from various reports. Using the card catalog at the University of Illinois library, we obtained materials dating from the early fifties.

The third phase of this literature search involved the solicitation of additional references from noted fault diagnosis and/or computer simulation experts. Over twenty such individuals were sent the list of references resulting from the first two phases of our literature search. They were asked to skim the list of references and suggest any additional references that they felt to be essential for a selected bibliography on human performance in fault diagnosis tasks. Approximately one-third of those queried responded. We greatly appreciate their contributions.

The materials in this bibliography are divided into the following three major areas:

1. Research Reports
   A. Primary Research
   B. Secondary Research

2. Manuals for Fault Diagnosis

3. Materials Indirectly Related to Fault Diagnosis

Primary research reports include empirical and/or theoretical studies aimed directly at human problem solving behavior in fault diagnosis tasks. Secondary research reports refer to literature reviews. As noted earlier, a representative set of training and field manuals is included in the "manuals" category. Indirectly related materials refer to studies of human behavior in related domains (e.g. medical diagnosis or problem solving in mathematics), reports that directly relate to fault diagnosis

but do not provide research results of a type necessary for the report to be categorized as a "research report." Since the number of items that could be placed in the "indirectly related" category was potentially enormous, we limited consideration to items that related to human behavior and particularly matched our interests. Thus, for example, the large body of literature on maintainability and automated fault diagnosis has been omitted from this bibliography.

Where possible, we used the abstract that accompanied an item. However, we usually had to supplement the abstract considerably in order to make it self-explanatory. The indexing of each item was based on a consensus of the authors.

We hope to periodically update this bibliography and re-issue it. To that end, we would appreciate suggestions and contributions. If possible, when submitting a suggestion for inclusion of a new item, please include a copy of the item.

PRIMARY RESEARCH

Bond, N.A., Jr.; Rigney, J.W. (1966) "Bayesian Aspects of Troubleshooting Behavior." Human Factors. 8:377-383.

Thirty-nine Navy technician trainees filled out a symptom-malfunction matrix on a blocking oscillator circuit. The particular sequence of checks used by each man on each problem was combined with his symptom-malfunction matrix, via a Bayesian algorithm, to yield computer estimates of failure likelihoods for each component. The computer program predicted actual parts-replacement behaviors in about half of the cases. Those technicians who start out with valid symptom-malfunction matrices are more likely to resemble the Bayesian processor. Subject's troubleshooting behavior that was characterized as Bayesian correlated with higher class standing and longer time between tests. It is suggested that symptom-malfunction matrix accuracy could be a training criterion. Students could be trained until they could produce a symptom-malfunction matrix to a high standard of physical validity.

7 pages, 3 references

Brooke, J.B.; Duncan, K.D.; Marshall, E.C. (1978) "Interactive Instruction in Solving Fault Finding Problems." International Journal Man-Machine Studies. 10:603-611.

Thirty subjects were divided into two groups which solved 60 trials of fault diagnosis problems. One group was given process information provided by the interactive software system when an incorrect diagnosis was made. At that point during the interaction, feedback regarding the possible failures was given to the subjects. Also, if subjects continued to ask for additional information when the solution was obvious, the system informed subjects of the fact that the failure could be identified. The control group had no feedback and were not informed about the correctness of their diagnosis. Analysis of variance showed a significant effect of training on learning.

9 pages, 2 references

Brown, J.S.; Burton, R.R.; Bell, A.G. (1975) "SOPHIE: A Step Toward Creating a Reactive Learning Environment." International Journal of Man-Machine Studies. 7:675-696.

This paper describes a fully operational AI-CAI system which incorporates artificial intelligence techniques to perform question answering, hypothesis verification and theory formation activities in the domain of electronic troubleshooting. Much of its logical or inferencing capabilities are derived from uses of simulation models in conjunction with numerous procedural specialists. The system also includes a highly tuned structural parser for allowing the student to communicate in natural language. Students can test components in an electronic circuit, develop hypotheses regarding the fault, and obtain feedback concerning why a hypothesis is incorrect. Replacement of parts is allowed only when the student can answer correctly queries about why he thinks the parts should be replaced. Although the system is extremely large it is sufficiently fast to be thoroughly exercised in a training or classroom environment.

22 pages, 11 references

Brown, J.S.; Rubinstein, R.; Burton, R. (1976) "Reactive Learning Environment for Computer Assisted Electronics Instruction." Lowry Air Force Base, CO: AFHRL-TR-76-68.

The development of several new computer based strategies for teaching troubleshooting principles to electronics technicians is described. The report documents an experiment in which those materials were presented to student technicians to determine their attitudes toward the techniques, and to determine whether the resulting training resulted in improvement of their technical skills. Results in both cases were positive with students responding very favorably to the materials and with their performance improving quantitatively and qualitatively after the instruction.

Seventeen college level students in an electronics curriculum were subjects in an experiment for evaluating alternative training and teaching methodologies on troubleshooting behavior. Subjects were divided into four groups, each group receiving a different sequence of teaching and training activities. Most of the evaluation is qualitative and based on extensive interviews and questionnaires. However, the fourth group was administered a pre-test for measuring basic understanding of power supply troubleshooting. This pre-test also included two faults to troubleshoot before the laboratory games began. A post-test was administered to measure the effect of computer-based activities on learning. Students' scores reflected their ability to make correct fault hypotheses given a set of symptoms. Improvement in all subjects' scores was found to be significant at the .05 level. Also, subjects experienced an average decrease in task time by 41%, significant at the .05 level.

140 pages

Crawford, A.M.; Crawford, K.S. (1978) "Simulation of Operational Equipment with a Computer-Based System: A Low Cost Training Technology." Human Factors. 20(2):215-224.

The feasibility and effectiveness of teaching performance skills using a computer-based training (CBT) methodology were investigated. Graphic simulations of the appearance and functions of a system in an anti-submarine aircraft were presented to students within an instructional framework. The objective was to determine whether CBT could be used for low cost, part-task training. The subjects were new co-pilot trainees for the S-3A anti-submarine aircraft. The performance of the 22 CBT students, as measured on a high fidelity simulator, was compared to that of 22 students who had gone through conventional training consisting of workbook study and hands-on practice in the simulator. Results showed that CBT students performed the necessary skills as well before practice in the simulator as conventionally trained students could after this practice. Performance measures were the number of tasks completed and the time to completion. The authors felt that CBT was an effective and low-cost means of part-task training of certain performance skills.

10 pages, 11 references

Crooks, W.H.; Kuppin, M.A.; Freedy, A. (1977) "Application of Adaptive Decision Aiding Systems to Computer-Assisted Instruction: Adaptive Computerized Training System (ACTS)." Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. PATR-1028-77-1.

This report describes the Adaptive Computerized Training System (ACTS) which combines the techniques of circuit simulation, artificial intelligence, decision modeling, and adaptive computer-assisted instruction to provide training in decision making. The ACTS incorporates an adaptive computer program which learns a student's diagnostic value structure and uses this structure to train the student in practical decision making. This report describes the development and operation of the ACTS as it is applied to training electronics troubleshooting.

Six college students with electronics backgrounds served as subjects in solving 45 fault diagnosis problems. Subjects were divided into three groups receiving the following initial aiding: 1) the expert's three best alternatives were displayed to the subject and after the subject's choice was made, additional feedback was provided by identifying the expert's best alternative; 2) subjects first indicated alternatives before expert's alternatives were displayed; and 3) no feedback or indication of expert's choice. Results indicate that those who received aiding or feedback solved problems at lower costs than subjects who received neither aiding nor feedback. Practice was shown to have a positive effect for all groups in terms of reducing costs.

54 pages

Elliott, T.K. (1966) "A Comparison of Three Methods for Presenting Procedural Troubleshooting Information." Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. Report No. AMRL-TR-66-191.

The effects of subject aptitude and performance aide mode of presentation on the performance of procedural, between-stage troubleshooting tasks on a real piece of electronic equipment were studied. The study used nondecison aids presented in three modes, namely, an automatic retrieval of visual information, an automatic retrieval of audio information, and a manual retrieval of visual information. Two aptitude groups (Air Force electronic index 40-60 and 75-90) with no previous electronic training or experience were given from 3 to 5 hours of task training before the experiment. Each subject solved 26 actual, and 11 synthetic problems. The study indicated no difference in effectiveness of aids using visual representations. Both were superior to audio presentations. The two aptitude groups were equally effective in performing troubleshooting tasks using nondecision aids. In comparison with a previous study using decision aids, the study showed nondecision aids produced superior performance on the same between-stage troubleshooting problems using similar subjects.

38 pages, 10 references

Elliott, T.K.; Joyce, R.P. (1971) "An Experimental Evaluation of a Method for Simplifying Electronic Maintenance." Human Factors. 13(3):217-227.

Two groups of subjects solved the same set of 13 troubleshooting and repair problems in seven solid-state-circuit modules which contained as many as five stages each. Both groups used the same hand tools and test equipment. One group was composed of 41 conventionally trained Air Force 5- and 7-level technicians who normally maintain such equipment as part of their jobs. The technicians used the same troubleshooting techniques they ordinarily used on their jobs, and they were provided with a performance aid resembling an Air Force technical order. The other group was composed of 20 high-school students with no prior training or experience in electronics. Their training for this study consisted of a 12-hour course in the use of hand tools and test equipment and in the use of the proceduralized troubleshooting aid evaluated in this study. The aid indicated which check to make based upon the outcome of previous checks. Using the proceduralized troubleshooting aid, the high-school students took significantly less troubleshooting time than did the experienced technicians using normal techniques; however, the technicians required significantly less repair time and made significantly fewer errors than did the students. These differences may be accounted for in part by differences in the tasks and scoring methods for the two groups, and there were no differences between the two groups on a number of other measures. However, the difference in training time and, therefore, cost of training between the two groups was so great as to suggest the possibility that job-relevant training and proceduralization of the task can introduce substantial savings, even after the cost of developing the special performance aids required by proceduralized troubleshooting is subtracted.

11 pages, 10 references

Ely, J.H.; Hall, N.B.; Van Albert, C.E. (1960) "Coding Electronic Equipment to Facilitate Maintenance." IRE Transactions on Human Factors in Electronics. HFE-1(2):66-69.

The aim of this study was to improve maintenance of electronic equipment by determining what information to place on the equipment and developing techniques for its display. Trips to various communications installations were made in order to examine equipment, observe maintenance activities, examine manuals, and interview personnel. Detailed data were collected showing the marked variation between observed test point readings and those called for in maintenance manuals. Recommendations were developed concerning information to be displayed on prime electronic equipment, covering 1) designation of functional groupings, 2) identification of signal paths, 3) identification and sequence for using test points, and 4) presentation of historical information for each test point. These recommendations were evaluated by incorporating them on an oscilloscope and evaluating the performance of 18 technicians. Comparing this "coded" scope with an identical uncoded one showed that troubleshooting time was reduced on the average to approximately one-half that for the uncoded equipment.

4 pages, 3 references

Finch, C.R. (1971) "Troubleshooting Instruction in Vocational-Technical Education via Dynamic Simulation." Pennsylvania Department of Education, Bureau of Vocational, Technical and Continuing Education. ERIC Document Reproduction Service ED 055 204.

This study used a commercial real equipment simulator to train automechanics for fault diagnosis. The research also explored the attitude of the students and the instructors towards the simulator. The experimental group received simulator practice, while the control group received no treatment. Those students who practiced on the simulator had better troubleshooting performance on four of the six criteria measures. The instructors were satisfied with the simulator, and the students believed that it was at least as good as traditional classroom or laboratory instruction.

107 pages, 21 references

Finch, C.R. (1972) "The Effectiveness of Selected Self-Instructional Approaches in Teaching Diagnostic Problem Solving." The Journal of Educational Research. 65:219-223.

This study examined the effects of three self-instructional approaches of teaching diagnostic problem-solving (troubleshooting). Two of the approaches attempted to simulate student-equipment interaction via programmed and text instruction while a third approach utilized actual equipment. After forty-five community college students received an orientation to equipment operation, fifteen were randomly assigned to each of the three treatments. Criterion variables included troubleshooting knowledge, troubleshooting performance, and attitude toward instruction received. Analysis of covariance indicated that the equipment approach was superior to non-equipment simulation approaches in terms of troubleshooting performance scores. Correlational analyses of criterion variables provided some evidence that relationships between attitude and behavior were dependent upon the instructional approach used.

5 pages, 10 references

Freedy, A.; Crooks, W. H. (1975) Use of an Adaptive Decision Model in Computer-Assisted Training on Electronics Troubleshooting. Woodland Hills, CA: Perceptions Inc., April 1975.

The report discusses a system for Computerized Decision Training (CDT). This system has the capability to compare subjects' troubleshooting decisions with the optimal as defined by "experts." The goal was to train for quality decision making rather than cookbook troubleshooting. The simulations are computer generated problems applicable to electronic circuits. The problems are presented on a CRT and permit the subject to: check symptoms, measure a component value, replace a module, or declare circuit to be fault free. The adaptive decision model was found to converge on the decision behavior of the students who quickly settle into consistent decision strategies. The authors' conclusion notes that there is a need for considerably more research in this area.

9 pages, 17 references

Glaser, R.; Damrin, D.E.; Gardner, F.M. (1954) "The Tab Item: A Technique for the Measurement of Proficiency in Diagnostic Problem Solving Tasks." Educational and Psychological Measurement. 14:283-293.

This work describes a method of fault diagnosis training relying on the "tab item." The tab item is a foldout cardboard flow chart which allows the troubleshooter to gather information by pulling tabs. This system provides the following: A symptom, check procedures, and a list of possible failures. This system therefore attmepts to reproduce the troubleshooting situation on paper. Measures for scoring troubleshooting performance which are discussed are: number of tests performed, number of redundant tests, test relevancy, and test adequacy. Although this article offers no empirical evidence of the instructional value of the tab item, it does speculate as to its potential value across a broad spectrum of technical training. Additional uses of the Tab Test can be found in Standlee (1956) and Fattu (1956).

10 pages

Glass, A.A. (1967) "Problem-Solving Techniques and Troubleshooting Simulators in Training Electronic Repairmen." Doctoral Thesis. Columbia University.

The purpose of this project was to study the practical and operational application of problem-solving concepts by introducing into the regular training of military electronic repairmen two experimental methods of teaching troubleshooting and to evaluate their effectiveness in promoting success. These two experimental methods were: 1. a series of recorded lectures dealing with problem solving methods, and 2. a series of paper and pencil troubleshooting simulators to provide the opportunity to apply problem solving techniques. There were two simulators, one commercial and the other custom-built. The main criteria for evaluation of the experimental variables were performance tests on actual electronic equipment (N=240). The method for administering and scoring the performance tests was the result of extensive pilot studies. The essence of the scoring method was to score for sequence of logic in troubleshooting, time, and solution success. The conclusions were: 1. Subjects receiving problem-solving lectures were superior on performance test to subjects not receiving them. 2. Subjects using simulators were superior on performance criteria tests to those not using the devices, but only when the custom-built device was used. 3. Subjects receiving a combination of lectures and devices were superior on performance criteria tests to subjects not receiving the combination. 4. The use of the custom-built simulator produced superior performance criteria test scores as compared to subjects using the commercial version, only when the lectures were used as well.

136 pages, 54 references

Goldbeck, R.A.; Bernstein, B.B.; Hillix, W.A.; Marx, M.A. (1957) "Application of the Half-Split Technique to Problem-Solving Tasks." Journal of Experimental Psychology. 53(5):330-338.

An experiment was designed (1) to test the hypothesis that the half-split instruction increased efficiency for simple problems and (2) to determine half-split efficiency for more complex problems. A second experiment was designed to determine whether additional practice, different methods of instruction, and more complex training materials would produce an improvement in the subject's ability to arrive at a set of alternatives, and, if so, whether the half-split method would then be more efficient.

In experiment I, 90 male university students participated as subjects and were instructed to replace a faulty unit in a troubleshooting task. Thirty were assigned problems to each of three complexity levels. Based on scores obtained from a problem solving test, subjects were randomly assigned to a control group and a group which received explicit instructions regarding the application of the half-split technique. Solution time for the half-split group was significantly longer than the control group. Increasing complexity resulted in an increase in the number of tests only for those subjects who scored low on the problem solving test. Results suggest that the half-split technique is superior under certain conditions, such as with diagrams of low complexity where subjects apparently had little difficulty in finding the trouble-possible units, and where subjects avoided incorrect replacements.

Experiment II was an attempt to improve the effectiveness of the half-split method by improving instruction and giving extended practice. Only problems of the highest level of complexity were used. Forty male university students participated and were randomly assigned to four training groups. The deductive half-split group was like the previous half-split group but given more practice. The instructions and practice given the deductive half-split group were more effective in reducing the number of tests than were the less extensive instructions in Experiment I. Results of both experiments indicate that the empirical superiority of the half-split technique is a function of the nature of the task, and the degree and type of training given the troubleshooter. From these experiments, it is now clear that future research on training methods should emphasize the more basic deductive phase rather than the relatively mechanical half-splitting aspect of the process.

9 pages, 3 references

Landa, S. (1972) CATTS: Computer-Aided Training in Troubleshooting. (R018-PR) Santa Monica, CA: Rand Corporation. ERIC Document Reproduction Service No. ED 066 888.

The Rand Corporation's Programmer-Oriented Graphics Operation (POGO) was used in the design, implementation and testing of a computer-assisted instruction course to train airmen in malfunction diagnosis - CATTS (Computer Aided Training in Troubleshooting). The design of the course attempted to reduce the problems of computer graphics for both instructor and student. The observations of Air Force instructors using the system suggest that the system is workable. No empirical evidence was gathered. The report emphasizes the POGO software more than troubleshooting.

108 pages, 11 references

Mallory, W.J.; Elliott, T.K. (December 1978) "Measuring Troubleshooting Skills Using Hardware-Free Simulation." Air Force Human Resources Laboratory, AFHRL-TR-78-47.

The hypothesis formulated was that troubleshooting performance on simulation would be predictive of the same tasks on real equipment. Sixteen instructors and fifteen beginning students in a precision measurement equipment course were given the same problems with two treatment levels. Problems were solved for criterion of job sample test (JST) and simulation or symbolic performance test (SPT). The task in each case was to locate the fault at the stage level rather than component level. Performance measures included mean percent correct solution, time to complete problems, and number of steps to completion. Statistically significant correlations indicate a high degree of similarity between the job sample test and symbolic performance test. An algorithm is presented which is used to evaluate problem difficulty. Correlation of the hypothesis problem difficulty with empirical problem difficulty (obtained by using test results of subjects) did not produce significant agreement. It was noted that the problem difficulty algorithm was insensitive to feedback loops which occurred in some of the problems and would be modified in the future.

120 pages, 25 references

Mills, R.G. (1971) "Probability Processing and Diagnostic Search: 20 Alternatives, 500 Trials." Psychonomic Science. 24(6):289-292.

Ss' capabilities for processing probability information in performing a diagnostic search task similar to troubleshooting is explored. Six Ss searched (queried) among 20 components in a series circuit to isolate a single component failure per trial. Failures were generated according to 10 alternative probability-of-component-failure distributions (D), each N = 500. Prior to performing their search on a trial, Ss predicted the failure for that trial. Of primary interest was the influence of varying D on predictions and search performance. Results indicate that: (1) distributions of predictions tend to match actual D in shape and location but exhibit certain characteristics; (2) probability of correct prediction is low and is influenced by D; (3) search strategies are suboptimal (The optimal solution required an average of 14% fewer tests.) but "logical" and to some extent predictable; and (4) in some instances, search strategy appears to be related to predictions.

4 pages, 13 references

Osborn, W.C. (1970) "An Approach to the Development of Synthetic Performance Tests For Use in Training Evaluation." presented at the 12th Annual Military Testing Association Conference, French Lick, Indiana.

This paper describes an approach to the selection of inexpensive alternatives to fully job-relevant performance tests. Based on the concept of content validity, the approach is to utilize the skill and knowledge required of the trainee as a criterion for assessing the cost and job-relevance of fabricated alternatives to performance tests. Two job tasks are analyzed to illustrate the concept.

6 pages

Rasmussen, J.; Jensen, A. (1974) "Mental Procedures in Real-LIfe Tasks: A Case Study of Electronic Troubleshooting." Ergonomics, 17(3):293-307.

An experiment was conducted at a nuclear research institute to investigate troubleshooting approaches used by skilled electronics repairmen during on-the-job tasks. A verbal record of the repairmen's strategies was collected for data analysis. Codes were applied to describe the heuristics employed: 1) topographic search - use the topographic location of measuring points; 2) functional search - use the normal functional relation between a feature in the system's response and a specific part in the system; and 3) search by evaluation of a fault. This last heuristic implies the human is using a mental model of the system relating changes to internal signals, parts or components to the changes observed in the system response. Results suggest that procedures considered unsystematic in a laboratory study may turn out to be rational and systematic when one listens to the individual's rationalization. Also, it was found that verbal records appear to be useful for recording rapid sequences of simple decisions based upon informationally redundant observations.

15 pages, 11 references

Rasmussen, J. (1978) Notes on Diagnostic Strategies in Process Plant Environment. Roskilde, Denmark: Riso National Laboratory, Riso-M-1983.

In the report are discussed some aspects of state identification and diagnosis in process plant control which must be considered in connection with automatic disturbance analysis and man-machine interface systems.

The content of the diagnostic process depends upon the overall goal of the diagnostician - whether it is to protect the plant, to maintain operation or to repair, and it may not necessarily include a determination of the cause itself. Important aspects of diagnosis include critical variables and causal flow paths which are intimately related to the paths along which events and changes propagate through the system, i.e. to the flow of energy, matter and information which together form complex, interacting flow structures.

In the process plant environment, a diagnostic task implies a search to identify a change from a normal or planned plant state. Several elementary strategies can be identified. In the report a distinction is drawn between two main groups - topographic search strategies, performed as search through the system with reference to a model of normal plant state; and symptomatic search strategies, performed as a search through a library of abnormal state models with reference to the actual plant state.

Typical properties of the different strategies are discussed such as processing capacity requirements and dependence upon a priori analysis.

The role of the elementary strategies in the overall diagnostic task is not discussed since this is considered possible only with reference to selected scenarios describing realistic and complex real life situations arising from disturbed plant operations. The aim of the report is to identify and formulate some of the issues which should be taken into account when creating such scenarios based on careful field studies and analysis of incident reports. Based on these scenarios, different overall diagnostic strategies can then be formulated and tested by simulator experiments.

36 pages, 12 references

Rigney, J.W. (1973) "A Discussion of Behavioral Technology Laboratories CAI Projects in Relation to a CAI Test-Bed Concept." Behavioral Technology Laboratories, Report No. 71, University of Southern California, Los Angeles, CA.

The elements of an instructional system are discussed and some literature bearing on the functions of these elements is reviewed, with the objectives of stimulating thought about an instructional system as a CAI test-bed and of pointing out some results of laboratory research, particularly in cognitive psychology, that are believed to be worthy of the instructional technologist's attention.

In the second part of the report, selected parts of CAI projects underway at the Behavioral Technology Laboratories are described in relation to instructional system elements, to give an overview of this research. The projects include: work on computer grahics to (1) simulate front-panel topography and functional organization of circuits, (2) facilitate interpretation of relative motion, and (3) create visual analogies for abstract concepts and processes to serve as the basis for students to develop their own internal representations; work on new methods for recording cortical evoked potentials and correlating them with learning and memory processes; work on a dynamic programming model for adaptive control of problem-solving types of CAI; and work on three-dimensional mock-ups of electronic equipment to be placed on-line with a CAI system.

40 pages, 46 references

Rigney, J.W.; Towne, D.M. (1969) "Computer Techniques for Analyzing the Microstructure of Serial-Action Work in Industry." Human Factors. 11(2):113-122.

Three computer-based techniques for analyzing and simulating serial-action tasks are described. The first, called BETS (a Bayesian model), measured the efficiency, in terms of expected information, of tests made by technicians who were troubleshooting malfunctioning electronic circuits. It computed efficiency ratios for a technician's test sequences in comparison to optimal sequences. The second method, ARMAN, generated detailed time-and-motion analyses from gross descriptions of serial-action tasks and man-machine interfaces and computed the time costs of these tasks.

The third technique incorporates a general model of the action-goal structure of serial-action work. It operates on this structure with special functions composed in a symbol manipulation language. This program, called TASKSYM, can generate all alternative correct ways to accomplish serial-action work and can track a subject through the performance of this work. The model includes an anti-goal structure which identifies action sequences leading to catastrophic error, e.g., electrical damage to the equipment or shock hazard to the performer. TASKSYM is extended with LISP to develop TASKTEACH which provides feedback on tests and errors, and offers various levels of help.

10 pages, 14 references

Rigney, J.W.; Towne, D.M. (1970) "TASKTEACH: A Method for Computer-Assisted Performance Training." Human Factors. 12(3):285-296.

A method for using a computer time-sharing system to assist the learning of serial tasks, from operating equipment through troubleshooting, is described. The method is based on mediational theory. The current resurgence of interest in mediational theory in psychological research is noted, and parallels between experimental strategies and instructional strategies for evoking and manipulating mediating processes are pointed out. Categories of processes which mediate performance of serial tasks are described. Procedures for facilitating the learning of these processes are implemented by a computer program, called TASKTEACH. The program sustains the student's performance of complex serial tasks by giving him variable amounts of support while helping him learn and organize the processes which mediate his performance of these tasks. The program generates output to the student during the learning session by processing short lists and the prior responses of the student. The lists, which are input to the program replace the conventional frame-by-frame description of an instructional sequence written in a "CAI language."

12 pages, 21 references

Rigney, J.W.; Towne, D.M.; King, C.A.; Moran, P.J. (1978) "Field Evaluation of the Generalized Maintenance Trainer-Simulator: I. Fleet Communications System." Behavioral Technology Laboratories, Report No. 89, University of Southern California, Los Angeles, CA.

The Generalized Maintenance Trainer-Simulator (GMTS) is a concept for giving students in Class C schools intensive practice in troubleshooting equipment and systems taught in those schools. It can be used for any device in which signal paths and their relationships to controls, indicators, and test points can be defined. The GMTS uses generative CAI. That is, it generates the interaction with the student by referring to his last inputs and to its stored history of interactions with him up to that point. To the extent that these individual student histories constitute models of individual students, GMTS constructs a model of each student to interact with that student. In addition to these features, GMTS is uniquely suitable for use in Class C school training. The computer program that implements the instructional system is indifferent to the specific equipment being taught. What specific equipment that is simulated by the GMTS is determined by loading two data bases for that equipment: one describing essential internal features of the equipment and the other describing the external features.

This is a report of a field evaluation of the GMTS applied to systems level troubleshooting in the UHF communications side of the Fleet Communications System. Twenty Class A school students waiting to enter C schools practiced solving thirty-five troubleshooting problems. Results were generally positive. With respect to practice, the students became uniformly more fluent at troubleshooting; mean times to solve a problem were decreased by a factor of two, and standard deviations of these time were decreased by a factor of five. Similar reductions existed for average number of extra replacements per problem. Also, students' attitudes toward the trainer were generally favorable. An additional field trial is underway, using the AN/SPA-66 radar repeater as the subject matter.

85 pages, 3 references

Robinson, J.E.,Jr.; Deutsch, W.E.; Rogers, J.G. (1970) "The Field Maintenance Interface Between Human Engineering and Maintainability Engineering." Human Factors. 12(3):253-259.

Field maintenance actions reported in a deployed air defense system were reviewed to determine and quantify (1) the nature of operator and maintainer influences on system malfunctions, and (2) the nature of man-machine problems being encountered by system personnel in actual diagnosis and repair activities. Maintenance events described in 213 problem reports from the field were categorized according to three probable sources of malfunction: primarily human, combination human and equipment, and primarily equipment. Human involvement in system malfunctions was clearly established in 25% of the events reported. Additional information contained in 21 documents analyzing system maintenance was examined. The nature of human influence on system malfunction is described by examples of "unfortunate" field maintenance, "ordinary" field maintenance, and troubleshooting deficiencies. Troubleshooting deficiencies were cited as a frequent problem observed by equipment contractors who had more knowledge and understanding than the technical personnel. The nature of reported man-machine problems highlighted the fact that human engineering participation in establishing maintainability design requirements can serve to make equipment that will be suitable to the presence and actions of human users.

7 pages, 5 references

Rouse, W.B., (1978) "Human Problem Solving Performance in a Fault Diagnosis Task." IEEE Transactions on Systems, Man, and Cybernetics. SMC-8(4):258-271.

It is proposed that humans in automated systems will be asked to assume the role of troubleshooter or problem solver and that problems which they will be asked to solve in such systems will not be amenable to rote solution. The design of visual displays for problem solving in such situations is considered, and the results of two experimental investigations (N=20) of human problem solving performance in the diagnosis of faults in graphically displayed network problems are discussed. The effects of problem size (9,25,and 49 components), forced-pacing, computer aiding, and training are considered. Results indicate that human performance deviates from optimality as problem size increases. Forced-pacing appears to cause the human to adopt fairly brute force strategies, as compared to those adopted in self-paced situations. Computer aiding substantially lessens the number of mistaken diagnoses by performing the bookkeeping portions of the task. Further, for self-paced situations, skills developed with computer-aided training are transferred to unaided situations.

14 pages, 52 references

Rouse, W.B., (1978) "A Model of Human Decisionmaking in a Fault Diagnosis Task." IEEE Transactions on Systems, Man, and Cybernetics. SMC-8(5):357-361.

Utilizing elementary concepts from the theory of fuzzy sets as well as several nonfuzzy heuristics, a model is presented of human decisionmaking in the task of troubleshooting graphically displayed networks. The performance of the model is compared to the results of two previously reported experimental studies. The ability of the model to represent human decision making as a function of network size, forced-pacing, and computer aiding is considered. The model is used to support the hypothesis that humans tend to discount the value of information about what has not failed in searching for the sources of malfunctions.

5 pages, 3 references

Rouse, W.B. (1979) "A Model of Human Decision Making in Fault Diagnosis Tasks that Include Feedback and Redundancy." IEEE Transactions on Systems, Man, and Cybernetics. SMC-9(4):237-241.

A previously reported model of human decision making in fault diagnosis tasks is extended to include situations where feedback and component redundancy are important considerations. The model is based on concepts from the theory of fuzzy sets. The results of an experiment with human subjects are reported and used to estimate the parameters of the model. The model is used to illustrate the notion that subjects who discount the importance of feedback loops tend to have considerable difficulty when they encounter problems having a large number of loops.

5 pages, 7 references

Rouse, W.B. (1979) "Problem Solving Performance of Maintenance Trainees in a Fault Diagnosis Task." Human Factors. 21(2):195-203.

Forty trainees in an FAA certificate program participated in an experimental study of troubleshooting of graphically displayed networks. The effects of network size, computer aiding, and training were considered. It was found that performance degraded as network size increased, improved with the use of computer aiding, and that skills developed with computer aiding were transferred to the unaided situation.

9 pages, 15 references

Rouse, W.B. (1979) "Problem Solving Performance of First Semester Maintenance Trainees in Two Fault Diagnosis Tasks." Human Factors. 21(5).

Forty-eight first semester trainees in an FAA certificate program participated in an experimental study of troubleshooting of two different types of graphically displayed networks. The effects of network size, redundancy, feedback, computer aiding, and training were considered. It was found that performance degraded as network size increased, degraded as the level of feedback was reduced, improved with the use of computer aiding, and that skills developed with computer aiding in one task were transferred to the other task.

4 references

Rouse, W.B.; Rouse, S.H. (1979) "Measures of Complexity of Fault Diagnosis Tasks." to appear in IEEE Transactions on System, Man, and Cybernetics, SMC-9(11).

The literature of complexity is reviewed and the distinction between perceptual complexity and problem solving complexity is discussed. Within the context of two particular fault diagnosis tasks, four measures of complexity are considered. These measures are evaluated using data from two previously reported experiments which employed eighty-eight subjects. It is shown that two particular measures of complexity, one based on information theory and the other based on the number of relevant relationships within the problem, are reasonably good predictors of human performance in fault diagnosis tasks. The success of these measures is explained by the fact that they incorporate the human's understanding of the problem and specific solution strategy as well as properties of the problem itself.

54 references

Saltz, E.; Moore, J.V. (1953) A Preliminary Investigation of Troubleshooting. Technical Report 53-2. Lackland Air Force Base, Texas: Human Resources Research Center.

Troubleshooting was investigated using radar, reciprocating engines, and remote control turrets as the hardware for malfunction analysis observation. The discrete types of equipment were chosen in an effort to promote generalizability. The following hypotheses were formulated and tested:

1. Good troubleshooters know more about the functioning of the equipment upon which they work than do poor troubleshooters.
2. Good and poor troubleshooters differ in previous experience.
3. Good and poor troubleshooters differ in intelligence.

10 pages, 4 references

Saupe, J.L. (1954) Troubleshooting Electronic Equipment: An Empirical Approach to the Identification of Certain Requirements of a Maintenance Occupation. Urbana, IL: University of Illinois.

The study attempts to identify the criteria for proficiency in a troubleshooting situation. The study provides "leads for the construction of proficiency tests which are important aspects of the efficient selection, training, and distribution of maintenance personnel." The goals of the research were:

1. to develop a psychological model by which to view troubleshooting behavior.
2. to test certain hypotheses taken from this model relative to aspects of the troubleshooting process
3. to illustrate an empirical approach to the identification of important objectives of training programs

Subject performance was evaluated on a simulated radio receiver and on a paper and pencil test. Empirical results were presented.

Standlee, L.S.; Bilinski, C. (1966) "Note on Simulated Vs. Actual Electronic Troubleshooting Performance." Perceptual and Motor Skills. 23:532.

This is a brief note on electronic troubleshooting performance. It discusses the two basic approaches to measuring this performance (1) measurement of performance on simulated and (2) actual electronic equipment. 114 subjects (Naval electronics technicians) were divided into two groups, one group troubleshooting with the simulator, and the other with actual equipment. Results indicated poor troublshooting performance with the simulator and proficient performance with the actual equipment.

1 page

Steinemann, J.H., (1966) "Comparison of Performance on Analogous Simulated and Actual Troubleshooting Tasks." U.S. Naval Personnel Research Activity, Memorandum SRM 67-1, July 1966.

This investigation compared the performance of a group of subjects assessed on a simulated troubleshooting task and on the identical actual troubleshooting task using real equipment. Subjects were 14 students in the experimental training program for Electronics Technicians, conducted by the Navy Training Research Laboratory, San Diego.

Analysis of results revealed that the simulated performance measure did not provide a valid estimate of performance proficiency on the actual task. Obtained negative inter-test correlations indicate that simulated test results would actually be misleading in terms of estimating actual performance scores. In addition to performance score discrepancies, there were observable differences in specific performance procedures and overall troubleshooting strategy attributable to the differences in test mode. Although the research design was weak, the evidence strongly suggests caution in assuming that a simulated performance measure, even with considerable face validity, will provide a valid estimate of actual performance on a common task.

12 pages

Stolurow, L.M.; Bergum, B.; Hodgson, T.; Silva, J. (1955) "The Efficient Course of Action in 'Troubleshooting' as a Joint Function of Probability and Cost." Educational and Psychological Measurement, 15(4):462-477.

This research focuses on the development of a probabilistic model of troubleshooting behavior which prescribes an efficient course of action in locating defects based on probabilities of failures and work time given particular symptoms. Data were obtained from maintenance records for 46 four-engine aircraft to obtain the probability of each possible cause of a particular set of diagnostic signs. Mean repair times were also completed for each type of repair. A complete method and a simplified method are described for determining an efficient course of action to be followed in reducing a set of possible causes of malfunction to the actual cause. The simplified method was proposed as an alternative to overcome the cumbersome calculations of the complete method. The simplified method uses the ratio of mean repair time to probability of failure to determine the course of action to follow in reducing the list of possible troubles. Results of the analyses of maintenance records were sufficiently encouraging to suggest that further research of this type be done for a variety of complex devices.

16 pages, 4 references

Towne, D.M. (1979) "The Automated Integration of Training and Aiding Information for the Operator/Technician." presented to the Third Biennial Maintenance Training and Aiding Conference. Orlando, Fla.

A responsive and intelligent device which can provide both training information and job performance aiding can be extremely efficient in utilization of hardware, software, and so-called course-ware. The hardware components useful for presenting automated instruction are essentially the same as those required to aid an operator or technician, viz., a versitile and fast microprocessor CPU, ample random access memory, ample bulk storage, and appropriate input-output media. While the software driving such a device may be a collection of relatively special-purpose routines designed to satisfy particular training or aiding needs, a large portion of this software may be common utility functions which respond to specific requests of the user or serve to manipulate data about the target equipment or data about the operator/technician. Finally, the data base which characterizes a target equipment can be designed in such a way that both training and aiding requirements are met without duplication or inefficiency of preparation effort.

Under a contract with Naval Training Equipment Center, Behavioral Technology Laboratories has assembled the hardware elements of such a system, designed the target equipment, and programmed routines for training novice operator/technicians and aiding equipment operation and maintenance.

21 pages, 5 references

Wescourt, K.T.; Hemphill, L. (1978) "Representing and Teaching Knowledge for Troubleshooting/Debugging." Institute for Mathematical Studies in the Social Sciences, Report No. 292, Stanford University, Stanford, CA.

An extensive review of the troubleshooting/debugging literature is covered from an artificial intelligence perspective. The authors were interested in measuring the effect of training, that is, exposure to specific debugging heuristics, on problem solving performance. Twelve subjects with relatively little programming experience participated. They were currently enrolled in a BASIC programming course. Subjects were randomly assigned to two groups (aided and unaided) based on a computer programmer aptitude battery. Aided subjects could refer to a text tutorial during problem solving sessions. The chronology of subjects' actions were judged according to 5 criteria relating to implementation of heuristics contained in the tutorial guidelines and success of attempted solution. Successful debugging grammars that would capture the subjects' strategies were not developed. Subjective judgments of participants on the research team were necessary to identify the extent to which each measure applied to subjects' strategies. Results indicated poor performance of both groups in solving problems. After the experiment large differences were found in post test scores attained on the computer programmer aptitude battery, and thus by chance, subjects assigned to the non-aided group had become better programmers since completing their course in BASIC. In conclusion, there were no strong results to show that the tutorial aid affected implementation of heuristics. It is suggested that a pedagogy is needed for teaching procedural rather than declarative knowledge.

141 pages, 31 references

SECONDARY RESEARCH

Czeh, R.S. (1957) "Studies of Complex Behavior and their Relation to Troubleshooting in Electronic Equipment." Alexandria, VA: Human Resources Research Organization.

This report is a review of the literature concerned either directly or indirectly with the troubleshooting of electronic equipment. Specifically, this review presents the most pertinent findings in the areas of problem solving and concept formation and indicates the manner in which these findings have impinged upon, or could impinge upon thinking about troubleshooting. The literature on troubleshooting is discussed and the final section outlines a research task designed to develop an efficient, generally applicable procedure for troubleshooting electronic, and to develop methods for teaching the procedure.

23 pages, 59 references

Edwards, J.; Norton, S.; Taylor, S. Weiss, M.; Dusseldorp, R. (November 1975) "How Effective is CAI? A Review of the Research." Educational Leadership, 33: 147-153.

This article summarizes many research studies that involved Computer Assisted Instruction. The CAI modes discussed are: drill and practice, problem-solving, simulation, and tutorial. The areas of CAI research discussed are:

1. CAI as a summplement to traditional instruction
2. CAI as a substitute for traditional instruction
3. Effectiveness of different modes of CAI
4. Comparison of CMI with other nontraditional methods of instruction
5. Compression of time
6. Retention of learning with CAI
7. Effectiveness according to ability levels

This literature review referred to 9 studies that showed that the combination of CAI and traditional instruction was distinctly better than traditional instruction only. As a substitute for traditional instruction, the findings were mixed with 9 studies finding CAI superior and 8 studies finding traditional instruction better. In all cases CAI was effective in reducing training time.

7 pages, 33 references

Fattu, N.A. (1956) A Catalog of Troubleshooting Tests. Indiana University: Institute of Educational Research.

This catalog contains examples of various kinds of troubleshooting tests. The justification for a catalog of troubleshooting tests is that it summarizes and illustrates materials assembled from widely scattered sources and makes them available to individuals who need the information but do not have time to assemble it. This catalog attempts to be representative rather than exhaustive.

Tests are reported in the following groups:

1. on-the job measures
2. performance tests
3. simulator tests
4. ARC or "tab" tests
5. pencil-paper and oral-interview tests.

The major difference between the troubleshooting research of the fifties and the troubleshooting research of the seventies is the use of computers for data gathering in the later efforts.

130 pages, 43 references

Fink, C.D.; Shriver, E.L. (July 1978) "Simulators for Maintenance Training." Air Force Human Resources Laboratory, AFHRL-TR-78-27.

This report reviews past and present applications of simulation to maintenance training. Emphasis is on describing issues, problems and areas for future research as identified by recent authors. There is little evidence from the literature regarding the degree to which simulators promote transfer of training to the field. Thus far, transfer research has demonstrated that simulators can increase proficiency during and at the end of resident training. A variety of research has also demonstrated that major variations in resident training cannot be correlated with job proficiency after a year or more in the field. It still remains to be shown conclusively that transfer of training affects performance during the first weeks and months on the job. If transfer does occur, it should have its most important and noticeable impact during these weeks. There is a need, therefore, for studies which examine the relationship between resident training, especially that supported by simulators, and on the job proficiency during the first one to three months on the job. Allocating the position of simulators and actual equipment systems in maintenance training requires research investigating the optimal sequence of tasks and training aids for maintenance training.

60 pages, 71 references

Foley, J.P., Jr. (1977) "Overview of Advanced Systems Division Criterion Research (Maintenance)." Air Force Human Resources Laboratory, AFHRL-TR-77-77.

A prime but seldom considered cause of the current high maintenance cost of DOD hardware, and thus the high ownership cost of systems, is the current criteria used by personnel systems to select, train, assign, and promote maintenance personnel. The current criteria emphasize the ability to obtain high scores on paper-and-pencil theory and job knowledge tests. This paper summarizes the many studies which indicate that such tests have little demonstrated relationship to ability to perform job tasks. Table 1 summarizes the current research on performance measurement and indicates for each citation the low correlations obtained in those experiments for various maintenance tasks and paper-and-pencil theory tests, job knowledge tests, and school grades. Based on an experiment conducted in the past by AFHRL, it was shown that graphic symbolic tests were more promising than symbolic tests in measuring job task performance. A maintenance task taxonomy is discussed and a hierarchy of dependencies is developed for electronic maintenance tasks. This conceptualization is considered necessary before identifying the relevant criteria in job task performance tests.

22 pages, 38 references

King, W. (1978) "New Concepts in Maintenance Training." Aviation Engineering and Maintenance, 2 (6): 24-26.

This article discusses the present status of Navy maintenance training in light of recent developments in CAI (Computer Assisted Instruction). The advantages of 2-D computer simulators and 3-D real equipment simulators for troubleshooting is the main focus of example. The author presents monetary comparisons between actual equipment trainers (AET) and simulators of both the computer and real equipment type. The best example is the cost comparison for the training of radio room technicians for the Trident submarine. The AET costs 20 million dollars compared to a 2 million dollar computer simulator. King believes that the utilization of computer simulations for maintenance training has the potential to surpass the savings offered by simulators for flight training.

3 pages

Standlee, L.S.; Popham, W.J.; Fattu, N.A. (1956) A Review of Troubleshooting Research. Indiana University: Institute of Educational Research.

This report is an annotated bibliography of the troubleshooting literature of the fifties. It contains a brief description of the work of nearly one hundred authors. The report is indexed with the following terms: general discussion, proficiency assessment techniques, training equipment or materials, analysis of job activities, evaluation of maintenance personnel, experimentation, bibliography. This report is invaluable to persons interested in the early efforts of fault diagnosis research.

127 pages, 110 references

MANUALS OF ACTUAL FAULT DIAGNOSIS OR TRAINING IN FAULT DIAGNOSIS

AVCO Lycoming. (1975) "AVCO Lycoming Reciprocating Engine Troubleshooting Guide." Williamsport, PA: SSP-475.

A manufacturer published list of problems, causes, and solutions that represents the more common and recurring problems encountered by mechanics when troubleshooting. The list is general and refers to turbocharged and normally aspirated engines. This manual is written for the professional mechanic and assumes that shop manuals and proper tools are available.

47 pages

Bean, R. (1974) Petersen's Basic Automotive Troubleshooting. Los Angeles,CA: Petersen Publishing Co.

This manual is a very basic guide for the novice or do-it-yourself automotive enthusiast. It includes an easy to follow symptom-cause format with illustrations. The book is divided into such chapters as the following: Troubleshooting the Brakes; Troubleshooting the Ignition System; Troublshooting Automatic Transmissions; Engine Oil Pressure Problems; and Troubleshooting with a Vacuum or Compression Gauge. Simple logic trees are included for the starting, ignition and fuel systems.

144 pages

Chilton Book Co. (1972) "Troubleshooting." Chilton's Mustang Repair & Tune-Up Guide. Radnor, PA: Chilton Book Company; 31-45.

A section of the manual is designed to aid in the rapid diagnosis of engine problems. The systematic format is used to diagnose problems ranging from engine starting difficulties to the need for engine overhaul. It is assumed that the user is equipped with basic hand tools and test equipment (tach-dwell meter, timing light, voltmeter, and ohmmeter). Troubleshooting is divided into two sections. The first, General Diagnosis, is used to locate the problem area. In the second, Specific Diagnosis, the problem is systematically evaluated. The format presents a malfunction system followed by a list of tests and procedures. The proper results of the test are provided in an effort to aid the troubleshooter.

15 pages

Glenn, H.T. (1971) Glenn's Auto Troubleshooting Guide. Philadelphia, PA: Chilton Book Co.

This manual is another example of a popular book written for the automotive enthusiast rather than the experienced mechanic. The specific areas that it covers are: emergencies, hard starting, engine failure, excessive oil consumption, engine noises, overheating, fuel system trouble, electrical system failure, ignition system failure, drive, transmission, and rear axle trouble, and power brake and power steering failure.

98 pages

Howard W. Sams & Co. (1973) Tune-up Service with Testing, Diagnosis and Troubleshooting Indianapolis, IN: Howard W. Sams & Co., Inc. 2nd Edition.

This manual covers the latest emission control systems, electronic ignition systems, electronic test equipment, and conventional engine analysis equipment. The troubleshooting section presents the familiar symptom/cause format.

72 pages

Mitchell Manuals, Inc. (1977) Diagnostic Guide. San Diego, CA: Mitchell Manuals, Inc.

The book contains information designed to aid the professional mechanic in diagnosis and repair of unusual automotive problems. Since many malfunctions are caused by incorrect, inoperative, defective or missing components, attention is focused on these problems and conditions. All information presented has been carefully compiled, primarily from factory service bulletins, pinpointing the cause of specific malfunctions. This diagnostic guide is designed to help the mechanic avoid potential problems and save time.

The book is arranged for quick reference in finding particular information. The book's main divisions are done by vehicle manufacturers: American Motors, Buick, Cadillac, etc. Within each of the divisions there are three areas of information:

1) troubleshooting and diagnosis
2) jacking, hoisting and towing
3) hood latch and safety release locations

142 pages

General Motors Corporation. (1978) Diagnosis and Repair Manual - Easy to Follow Graphic Troubleshooting Procedures. Southfield, MI: General Motors Corporation.

This manual contains graphic mode diagnosis and repair charts. They are a relatively new approach to systematic diagnosis and repair. The charts are easy to use since they require minimal reading. The sketches of exact engine parts allows the mechanic to proceed to work without reading a manual, although on complex repairs the book emphasizes that a manual should be used.

These diagnosis procedures apply to various automotive systems in most 1970 thru current GM cars and light-duty trucks, with some procedures applying to even earlier model years. The procedures are based on the fact that the vehicle worked right at one time and the problem is due to time, wear, dirt or other causes.

201 pages

MATERIALS INDIRECTLY RELATED TO FAULT DIAGNOSIS

Berner, W.S.; Hamilton, L.A.; Best, W.R. (1974) "A New Approach to Evaluating Problem-Solving in Medical Students." Journal of Medical Education. 49:666-672.

This paper describes the development of a new technique to assess clinical problem-solving skills in medical students. The procedure enables each step in the solution of clinical problems to be evaluated independently by providing feedback to students at each decision point. There are several unique features, including the incorporation of some aspects of the problem-oriented medical record. Students were required to read an extensive data base and construct problem lists, order diagnostic tests, and plan for the management of the patient. The technique was designed to (a) be administered to large groups of students, (b) be easily scorable, and (c) overcome some of the difficulties inherent in previously developed means of assessment.

7 pages, 11 references

Brown, J.S.; Burton, R.R. (1978) "Diagnostic Models for Procedural Bugs in Basic Mathematical Skills." Cognitive Science. 2(2):155-192.

A new diagnostic modeling system for automatically synthesizing a deep-structure model of a student's misconceptions of bugs in his basic mathematical skills provides a mechanism for explaining why a student is making a mistake as opposed to simply identifying the mistake. This report is divided in four sections: The first provides examples of the problems that must be handled by a diagnostic model. It then introduces procedural networks as a general framework for representing the knowledge underlying a skill. The challenge in designing this representation is to find one that facilitates the discovery of misconceptions of bugs existing in a particular student's encoding of this knowledge. The second section discusses some of the pedagogical issues that have emerged from the use of diagnostic models within an instructional system. This discussion is framed in the context of a computer-based tutoring/gaming system developed to teach students and student teachers how to diagnose bugs strategically as well as how to provide a better understanding of the underlying structure of arithmetic skills. The third section describes our uses of an executable network as a tool for automatically diagnosing student behavior, for automatically generating "diagnostic" tests, and for judging the diagnostic quality of a given exam. Icluded in this section is a discussion of the success of this system in diagnosing 1300 school students from a data base of 20,000 test items. The last section discusses future research directions.

38 pages, 30 references

Ellery, G.L. (1977) "The EE's Role in the Garage Diagnosis of Vehicle Faults." Proceedings of 1978 IEEE Conference on Vehicular Technology, Denver.

The complexity of modern automobiles, trucks and other internal combustion engines demands more sophisticated, computerized diagnostic equipment. The requirement of high fuel economy and low hydrocarbon emissions further highlights this need. The author discusses the fact that automobile manufacturers are increasing their involvement in the design and construction of automated test equipment. The R & D for such equipment is the combined effort of the EE, ME, and Automotive Service Engineer.

Computer controlled test equipment which relies on micro-processor technology is already found in many automotive repair facilities, but the sophistication of such equipment is rapidly increasing. The author offers examples of electrical analysis of starter-motor-current oscillation and analysis of ignition spark amplitude to determine engine compression.

3 pages

McGuire, C.H.; Babbott, D. (1967) "Simulation Technique in the Measurement of Problem-Solving Skills." Journal of Educational Measurement. 4:1-10.

Employing simulation technique analogous to that utilized in management games and military exercises, the authors have directed the development of a series of branched problems in patient management requiring sequential analysis and decision. These problems are designed to measure aspects of behavior defined by a criterion group as essential components of clinical competence. The materials are suitable to either paper and pencil or on-line application. The validity and reliability of simulations is also discussed.

10 pages, 13 references

McGuire, C.H.; Solomon, L.M.; Bashook, P.G. (1976). Construction and Use of Written Simulation. United States of America: The Psychological Corporation.

This work is a comprehensive discussion of written simulations. The discussion ranges from basic definitions through construction, use and evaluation of simulations. The book is additionally applicable to computer simulations, or real equipment simulations. Sample problems are presented throughout the book.

Murray, T.S.; Cupples, R.W.; Barber, J.H.; Dunn, W.R.; Scott, D.B.; Hannay, D.R. (1977) "Teaching Decision Making to Medical Undergraduates by Computer-Assisted Learning." Medical Education. 11:262-264.

This paper describes a computer-assisted learning (CAL) program that is used on an open-acess basis by students at the University of Glasgow medical school. The authors report an experiment in which the experimental group (n=12) was presented with on-line case studies in which they had to decide on patient treatment. Upon completion of the experiment, the experimental group scored higher on a factual knowledge test and had improved decision making skills based on comparison of their scores to those of medical experts. The subjects felt that CAL enabled them to consider and discuss clinical decisions in a way that is both more realistic and more instructive than is possible in the more orthodox clinical teaching.

3 pages, 9 references

Swain, A.D. (1961) Factors Affecting Degree of Automation in Test and Checkout Equipment. Stamford, Conn.: Dunlap and Associates, Inc.

This report deals primarily with the human factors problems attendant to the increasing automation of weapon system test and checkout actions. The purpose of the report is to identify unfavorable tactical situations resulting from less-than-optimum allocation of test and checkout actions, from inadequate design of automatic checkout equipment (ACE), or from particular management or other practices related to the utilization of ACE. These cases suggest ways of avoiding such situations in the future. While most of the examples are taken from Air Force weapon systems, some are taken from Army and Navy weapon systems and equipment; and the principles and guidelines are generally applicable to all the services. It is only the application which should be different, as considerable differences often occur between services in such areas as training, manpower selection, environmental conditions, and logistics support (to name only a few differences in system criteria).

224 pages

Wollmer, R.D.; Bond, N.A., Jr. (1975) "Evaluation of a Markov-Decision Model for Instructional Sequence Optimization." Behavioral Technology Laboratories, Report No. 76, University of Southern California, Los Angeles, CA.

Two CAI programs in electronics and trigonometry were written to test the Wollmer Markov Model for optimizing hierarchical learning; calibration samples totalling 110 students completed these programs. Since the model postulated that transfer effects would be a function of amount of practice, half the students were required to complete one practice problem successfully before moving to the next stage; the other half had to do two practice problems successfully.

All students completed the courses satisfactorily. Practice effects were small; students who had one success in each stage did about as well as those who had two successes. The Wollmer model was thus not suitable for optimizing instruction, in terms of minimizing overall time, in these particular courses. Perhaps the main reason for this result was that, as the student works up to the top of the hierarchy, the sheer number of subskills involved in the final task becomes a major determinant of performance time, and number of practice trials has a relatively minor effect, unless a very large number of practice trials is given. To see if a much larger amount of practice would affect time to perform, three additional subjects were run with the electronics problems under the condition that 5 correct solutions were required at each of 11 levels. It was found that a much larger training time was required to get a 2-3 minute improvement at the final level. Because of this relative inefficiency, the Wollmer model would not prescribe such extensive additional practice.

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