Men and computers—

Sixth Annual Symposium on Human Factors in Electronics

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One of the major themes underlying the Human Factors Symposium in Boston this May was the crucial relationship between men and computers. In general, it was said, our computers are rapidly becoming so economical that now we are obliged to find ways of making better use of the people who use the computers. The problem of man-computer interaction, the man-machine interface, has come to the foreground.

In man-computer interactions, the role of the man runs the gamut from very simple actions like the pushing of a button all the way to highly sophisticated functions that characterize intellectual activities like problem solving. It should be noted that studies of data-entry devices and consoles, which were discussed in some of the earlier sessions, form a well-known and fairly refined part of human factors research and engineering. However, there are other kinds of man-computer interaction that give rise to a wide variety of more complex problems. Some of these involve man's own time-sharing activity; others derive from the requirement that he control exceedingly complex systems. These are situations that have been little studied, or, at least, studied in an ad hoc fashion, and many human factors researchers believe that it is now time to attempt to make more sophisticated mathematical descriptions of them. Such descriptions are necessary if a proper integration of man and complex machines is in fact to occur.

The advent of time-shared computer systems as a (soon to be) common adjunct of each man's office, makes the development of adequate languages and adequate input-output devices mandatory, if the full value of the time-sharing is to be had. The ease with which on-line time-sharing demonstrations were put on at the meeting was astonishing to most of those who observed them, and gave more than a hint of the probable future.

In general there was a larger component of theory and a lesser one of empiricism than has been characteristic of earlier meetings of this group.

Many aspects of human factors research and engineering and their application to the design of systems were discussed in the three days of the meetings. These will be all too briefly outlined in what follows.

Devices and techniques

Papers of the first session were given over to the subject of devices and techniques for operator input to computers. Input devices were discussed in a variety of contexts, from well-defined repetitive tasks to situations where it is quite difficult to define the human operator's role.
The modern hospital is one place where heavy clerical burdens, consisting of a constant exchange of information among nurses, patient service, and administrative stations, could be relieved by a computer-based information handling system. What is needed in such a system is an efficient manual information entry terminal for receiving and entering medical data. F. J. Minor and G. G. Pitman (IBM, Endicott, N.Y.) described a simulation study of computer entry devices for use by nurses in a hospital. The nurse, a focal point for information gathering and processing in the hospital routine, must receive requests from physicians, request tests, patient services, etc., and make decisions regarding patients' progress. She communicates and records these decisions through a computer teletype. Speed and accuracy measurements were made with several special teletype consoles and associated command coding schemes. One of the findings of this study was that a terminal consisting of an array of buttons, each associated with some term, instruction, etc., is more suitable for the data entry task than a typewriter terminal.

J. R. Cornog (National Bureau of Standards, Washington, D.C.) and J. C. Craig (U.S. Post Office Depart-

ment, Washington, D.C.) reviewed field trials conducted by the Post Office Department with various keyboards and coding systems used for sorting mail in post offices. The quantity of mail being handled suggests that tremendous savings can be effected even by very small improvements in coding and handling techniques. Thus, one major goal of Post Office mechanization schemes is a reduction in the number of times a piece of mail is handled.

For those who worry about the usefulness of the Zip Code, Dr. Cornog gave some inside dopester information. "It really works," she confided, "you get your mail a day earlier."

R. Rosenberg (M.I.T., Cambridge, Mass.) described a computer-based system for teaching the fundamentals of physical dynamic systems (electrical, mechanical) to college undergraduates. The system uses a special form of coding between physical elements, called Enport, which was developed by H. M. Paynter of M.I.T., and which has a format superficially like chemical bond graphs (see Fig. 1). The great advantage of Enport for computerized teaching is that the student can synthesize systems on a teletypewriter and ask questions about their behavior in a language that is isomorphic with the system differential equations.

**Human control behavior**

Specific mathematical models for human operators acting as control elements in closed-loop feedback control systems were discussed in a session on computer simulation and control.

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**Fig. 1. Bond graphs, which can be used to describe lumped parameter systems that obey the law of conservation of energy, are composed of nodes and bonds. Nodes describe particular types of energetic behavior (such as dissipation or storage); bonds indicate an energy transfer link between two incident nodes. A—Some bond graph elements with their electrical and mechanical interpretations. B—A simple system in bond graph language.**
G. L. Teper and H. R. Jex (Systems Technology, Hawthorne, Calif.) described analysis methods and human response models used in the design of manual controls for a booster of the Saturn V Class. The possible roles of the pilot as a parallel element to an automatic system, as a monitor of an automatic system, and as the sole controller of the booster system were described. Teper gave quantitative criteria for "minimal" and "good" control.

In all, STI analyzed four basic pilot-booster systems based on human pilot describing functions. A separate study by NASA based on simulation studies considered three. The two studies, when compared, were strikingly similar in their conclusions, even though they had been developed wholly independently and through fundamentally different methods. In effect, the more conventional NASA methods validated the STI technique, and paved the way for greater acceptability of such analytical methods in the future. It has been estimated that analytical studies could result in very significant reductions—on the order of 40 to 60 percent—of the time and effort required for similar simulation studies.

Continuing from a previous study of the human operator as a two- and three-state relay controller of a pure inertial system, R. W. Pew (University of Michigan, Ann Arbor) characterized human response as a sequence of discrete decisions that represent switching lines in the phase plane. He showed that humans use target velocity to determine these switching lines, and that switching criteria are dependent also upon the type of display used—that is, upon the way in which target velocity is displayed.

A third paper in this session (W. W. Wierwille and Gilbert A. Gagne, Cornell Aeronautical Laboratory, Buffalo, N.Y.) presented a deterministic method for characterizing the time-varying dynamics of human operators. Their method is unlike statistical techniques, which involve finite time averages or methods using steepest descent parameter tracking. This technique gives a best estimation of the time-course of parameters for various levels of relative trade-off between time resolution and amplitude uncertainty.

**Human extensions**

A session on remote manipulation, sensing, and robotics dealt with a very important field of research aimed at the functional extension of man to compensate for physical impairment, to permit manipulative activity in hostile or remote environments, or even to enhance his natural capacities.

A controller worn on the head with which a paraplegic can guide a motorized wheel chair was described by Donald Selwyn (Oakland, N.J.). Applicable in various contexts, the device uses inertial sensors to detect discrete head movements and translates these into electric pulses that govern appropriate servos (see Fig. 2). The handicapped person who uses it daily has found the discrete control easy to use and very effective.

Head motions, which would normally direct the gaze of an observer, can also generate signals to direct the "gaze" of a remote television camera. If the human operator is also equipped with a TV monitor that moves with his head, a highly "compatible" remote viewing system is created, according to William Bradley (Institute for Defense Analysis, Washington D.C.). The ability to look about in a remote environment using the same movements that would be appropriate to local observation is especially suited to remote manipulation.

At very great distances, such as those arising in space exploration, the projection of a human operator's motor and sensory capabilities into the remote environment is made more difficult by the delay due to round-trip signal transmission time. William R. Ferrell (M.I.T.) reported studies of remote manipulation. With delays of 0.3 second or more, operators tend to adopt a strategy of performing as much as they can without feedback; they then pause for one delay time, following which correct positional feedback is obtained. This tactic is repeated until the task is accomplished. The method permits complex and difficult manipulation tasks to be performed without instability.

Because of very long delays or other barriers to communication, systems to extend man's functions will, in the future, rely less on the operator's controlling from within the loop and more on his supervision of an "intelligent" manipulator that can process information and
make decisions itself. The process of learning to recognize features of the environment is, for animals, a cooperative enterprise of "hand" and eyes. Louis Sutro (M.I.T.) reported on efforts toward development of a system, based on animal functioning, using both visual and tactile inputs in a coordinated manner, able to become familiar with and to recognize objects.

Development of an exoskeletal brace that can be programmed to provide a variety of useful motions for a paraplegic has led investigators at the Case Institute Design Center to look extensively into the question of computer-aided manipulators. The philosophy underlying this research is that an operator need only specify the destination or desired position for the hand of the manipulator, and the control computer will generate the required motions to reach that destination. However, the problems involved in generating such movements are not as simple as might first appear, as an examination of the movement possibilities of the remote manipulator suggests (see Fig. 3). Development of criteria and programs to decide how kinematically indeterminate arm structures should be moved to obtain point-to-point hand movements was discussed by Peter Hammond. He reported on a path optimization scheme, jointly developed with Harold W. Mergler, which minimizes the instantaneous momentum in the arm.

Amplification of man's functional capacity through manipulators will require feedback loops involving the terminal devices but not directly including the operator, according to Edwin G. Johnson (AEC/NASA Space Nuclear Propulsion Office). Such localized loops, which can range from simple protective devices to recognition and decision-making systems, will free the operator from routine information processing and can potentially give him a more effective role in monitoring system behavior.

Man-computer operations

A session on joint man-computer operations for on-line management and command planning consisted of four papers. The first, by J. C. Emery (M.I.T.), presented a theoretical and analytic model of organizational planning developed from the viewpoint of information processing within management structure. Three papers, presented by E. L. Lafferty and E. M. Bennett (The MITRE Corporation, Bedford, Mass.), dealt with case studies of three joint man-computer systems currently operational at varying levels of completeness. These systems are meant to facilitate management and command planning. The first of these described the current U.S. Air Force Headquarters Operations Planning System; the second reported on an on-line data manage-

Fig. 3. Remote manipulator can be pivoted about the axis of the tube, and has pivots with horizontal axes at the shoulder, elbow, and wrist. Thus, the manipulator has seven degrees of freedom, while the position of the "hand" can be described by five coordinates (x, y, z, azimuth, and elevation).
ment system currently in use by the U.S. Strike Command; and the third reported on a prototype display-oriented on-line planning system currently operating in the MITRE Corporation's Systems Design Laboratory. All three studies described the capabilities of the various systems and showed photographic records of the man-computer interface that characterized each.

**Design of computer consoles**

Console design problems both in the U.S. and abroad were discussed in the session on computer operator and maintenance consoles. D. H. Keene (Electronics Associates, Princeton, N.J.) described the problems of grouping controls and indicators on the Electronics Associates 8800 computer. J. C. Jones (Manchester College of Science and Technology, Manchester, England) discussed the systematic design of the computer-operator interface on the British AEI-1010 computer, emphasizing the use of matrix graphical aids for recording and referring to functional interactions in the process of design. W. H. Brandenberg (United Ait Lines, Chicago, Ill.) pointed out the excessive emphasis on processors and memory systems as compared with input-output devices, implying that there are great gains to be made by small improvements in the latter. R. S. Hirsh (IBM, Los Gatos, Calif.) gave specific examples of this in terms of various keyset configurations for computer systems.

**Man-computer communication**

One of the most popular sessions was on the use of engineering languages for on-line man-computer communication. The topic was discussed by a panel of experts, including J. C. R. Licklider and F. D. Skinner (IBM, Yorktown Heights, N.Y.), D. B. Yntema and J. Weizenbaum (M.I.T.), C. Weissman (Systems Development Corporation, Santa Monica, Calif.), G. Shaw (Rand Corporation, Santa Monica, Calif.), and B. F. Green, Jr. (Carnegie Institute of Technology, Pittsburgh, Pa.). There were live demonstrations on computer consoles tied in with the M.I.T. Project MAC (Machine Aided Cognition or Multiple Access Computer), BBN's time-shared computer, the Dartmouth College-General Electric time-sharing system (the computer being located at Phoenix), and Systems Development Corporation's computer in Santa Monica. A banquet speech by Project MAC's director, Robert Fano, complemented this session by pointing to the promise of the time-shared computer in teaching and research applications.

**Information-processing models**

Models for monitoring and information processing in man was the theme of the final session. Three papers dealt with the sampling of information from many external sources—characteristic of human behavior in real life but neither well investigated in the laboratory nor included in the descriptions we have for man based upon laboratory research. L. T. Gregg (General Dynamics/Astronautics, San Diego, Calif.) hypothesized that man scans visually (and periodically) over a number of display functions until an out-of-limit indication is reached. The "Logical Model for Logical Man" then acts to correct the out-of-limit condition. The behavior of the model can be specified by a set of Boolean functions. Predictions by the model compared very well with laboratory data gathered from human subjects who monitored many meters.

J. D. Gould and Amy Shaffer (IBM, Yorktown Heights, N.Y.) pursued a similar line and produced results that showed how the number of correct responses in a multichannel terror detection experiment declined as the number of channels increased and as the available observation time per display decreased. A third closely related paper, but in an auditory instead of visual context, was presented by H. M. Kaufman, R. M. Glorioso, T. L. Booth, and R. M. Levy (University of Connecticut). They carried out experiments in which they varied signal-to-noise ratios (S/N) and clipping thresholds (T). Results indicated that human operators can maintain a consistently high detection performance level over the range of S/N and T studied; the number of trials to reach a decision followed the theoretical optimum predicted by analytical studies.

**Human factors and the automobile**

The following two papers, in a somewhat different context, developed mathematical models to describe how the human operator (of an automobile, aircraft, etc.) uses information that can be previewed before a response to it is appropriate.

T. B. Sheridan (M.I.T.) showed how the ability to preview the input course, along with the high-speed computation of an optimal trajectory, can effect great savings of effort and error over what is possible with a conventional servomechanism. Empirical results corroborated the model's predictions.

J. W. Senders (Bell Beroak and Newman, Cambridge, Mass.) presented a model—and the results of some corroboratory experiments—for the information processing behavior of an automobile driver. The driver in the experiments was permitted only brief periodic views of the road ahead. The model assumes a fading memory for the information available during the view and an input uncertainty rate in terms of bits per unit length of roadway. The predictions of the model and the data from the first experiment are in good agreement.

In the closing hour of the Boston meeting, John Senders, Chairman of the Symposium Committee, in an artfully droll yet serious disquisition, pressed home the point that a great deal of human-factors research is needed in relation to the automobile, in view of the massive death rate from its use. It is a field virtually untouched, yet (from accident statistics alone) demonstrably one that should awaken the gravest concern among human-factors engineers. Both the automotive and information revolutions are having a profound effect on individuals and society. The impact of the automobile is not only metaphorical. While information processors may do away with jobs, automobiles often bring even greater griefs.

The fact that two final papers at this meeting dealt with questions relating to the use of automobiles may presage more urgent action among human-factors engineers and psychologists. Perhaps an entire human-factors symposium should soon be devoted to the automobile, and to the technical and social problems that it has forced upon us.

* I had nothing to do with the writing from this point on.

JWS.