Applied Ergonomics, 6.3, 159–163

Ergonomics in action

Human Factors at SUNY at Buffalo

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In this further contribution to the Ergonomics in Action series, the authors review work at SUNY in terms of the historical background, teaching, theoretical and applied research and future prospects.

Industrial Engineering (the North American equivalent of Production Engineering in Europe) is concerned with predicting the behaviour of complex systems which include the human operator as an important component. A department with such a title must, by its very nature, draw fine balances between the study of human and inanimate components of systems, between theoretical strength and applications, and between teaching and research.

The balance within the department at SUNY is between mathematical modelling expertise on one hand and the human sciences on the other. The modelling skills have greatly enhanced the human factors tasks of modelling human performance. Similarly, the scientific measurement and understanding of human performance has permitted much more realistic models to be built by the operations researcher. This complementary quality has caused the development of parallel efforts within the same department.

The history of the department can be divided chronologically into three phases each of which is discussed further below. Phase 1 extends from the formation of the department in 1945 to 1962 when the University of Buffalo, then a private University, became a unit of the State University of New York. During this phase, under the leadership of Frederick H. Thomas, the primary emphasis was toward undergraduate education.

Phase 2, commencing with conversion to the SUNY system, extended to about 1970. During this period, under the Chairmanship of Wayland P. Smith and Kenneth R. Laughery, the major character changed to the balanced operational research/human factors effort still characterizing the department today. Major revision of the undergraduate curriculum occurred along with establishment of the MS (actually begun in the late 1950's) and the Ph D.

The 1970's under the Chairmanship of Warren H. Thomas constitutes the third phase in our history where programmes have become more firmly defined and established. More important, this phase is witnessing the attainment of totally new physical facilities on the new Amherst Campus. Although planning started as early as 1965 it was not until 1970 that planning in earnest began. Construction of the Industrial Engineering building began in 1972 with full occupancy in Summer 1975.

Below we have attempted to capture the essence of the educational and research programmes over the years in the department and to give a flavour of where we see things going in the future.

The teaching effort

The School of Engineering was formed in 1946 after plans in the early 1930's to do so had been deferred by the depression and then the war. Buffalo is probably unique in selecting Industrial Engineering as one of the set of original departments being established along with Mechanical Engineering. Soon after, Electrical Engineering was founded followed by Civil Engineering in 1958, Chemical Engineering in 1961, and finally Engineering Science (with Aerospace and Nuclear) in 1970.

The curriculum in the early days introduced students to human problems in industry with courses in methods engineering and labour problems. However, by 1952 courses in job evaluation and industrial safety had been added. Only minor changes in the concern for the human occurred over the next decade.

With the change from being a private university to becoming a major unit of SUNY in 1962 came the beginnings of a major shift in departmental emphasis. W.P. Smith became chairman in that year and guided the evolution of the department for the next six years. 1963 saw the addition to the faculty of K.R. Laughery, with a joint appointment in psychology, and with him the addition of human factors electives and man/machine systems design to the curriculum. Furthermore, approval to grant the MS degree was received followed subsequently by the Ph D. In 1966 the first Ph D was granted. Since then on average 25 BS, 15 MS, and 2 Ph D's have been awarded each year.

Instructional efforts were aided by John Fletcher from 1965 to 1968 followed by Gavriel Salvendy in 1968 (who transferred to Purdue in 1971). Lewis H Geyer arrived in 1970, Colin Drury joined the staff in 1972 and Myron Zajkowski in 1974.

The gradual evolution of both the undergraduate and post-graduate programmes has made it possible to offer a wide range of core courses and options in Human Factors, covering anatomical, physiological, psychological, and sociological factors as well as applications. It has been a feature of the department to integrate Human Factors with the more mathematical aspects of the discipline. Courses covering such topics as Computer Simulation of Human Behaviour and Human Factors in Quality Control are ways in which this close interrelationship has been demonstrated in the teaching of Industrial Engineering.

Research – theoretical and applied

With the coming of full time faculty staff in Human Factors, the output of research and industrial problem solving in this area was considerably augmented. The thread of measuring, predicting, and enhancing human skills runs through this research effort despite changes in the particular interests and skills caused by changing personnel over the last 12 years. This increase in activity was accomplished by equipment for a Human Factors laboratory which includes soundproof chambers for environmental studies, timing and stimulus presentation apparatus and work physiology recording equipment.

The research of Ken Laughery is well known in the field of cognitive psychology, particularly memory processes. Applications are also important and a fruitful relationship with Cornell Aeronautical Laboratories (now Calspan Corp) was established. This led to a series of studies on driver behaviour (eg, Anderson, Kidd & Laughery, 1967) which again brought together the Human Factors and operations research expertise in simulations of traffic behaviour at intersections. This simulation was based on a very detailed task analysis of the intersection behaviour and used measures and estimated characteristics of the driver, the vehicle and the intersection to produce speed/time curves for various manoeuvres. When these were compared with measured values on the road very good agreement was obtained.

Another fruit which grew from this early applications work was a series of studies of facial recognition, aimed at clarifying the processes by which humans search a large sequence of photographs for a potential 'suspect' in criminal investigation work. Early work showed that the probability of detecting the target face went down as more and more faces were seen. Equally disturbing was the fact that false alarms increased with number of faces seen. Further tests showed that there was no difference between men and women on the task and that extra knowledge about the suspect is only useful when the 'target' appears early in the sequence.

A thorough analysis of the facial recognition task was undertaken which involved isolating significant facial features and their dimensions and having subjects scale these. The culmination of this work (so far at least) is a Computer Aided system (Fig 1) in which the subject (eg, victim of a crime) interacts with an on-line computer to dynamically re-order the set of faces and hence improve the chance that the target occurs early in the sequence. A test of a prototype system (Lenorovitz, 1975) showed that a hit rate could be doubled and false alarms reduced almost to zero using such a system.

The major applications of the work physiology effort came with the appointment of Gavriel Salvendy in 1968 and his work (Salvendy and Pilitsis, 1971) on the physiological efficiency of the freely chosen pace of work in a strenuous task.

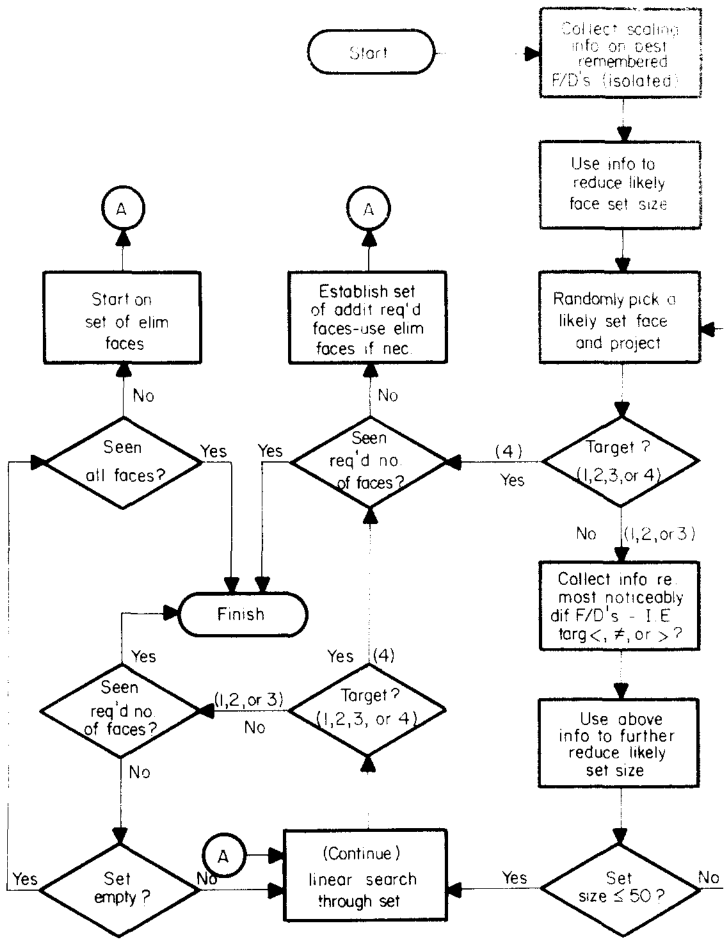

Fig. 1   Flow chart for CAPSAR logic

Two major projects on human skills were undertaken, combining techniques of traditional industrial engineering and experimental psychology and expanding the pioneering skills analysis work of Seymour. The first of these was to develop a new training system, based on the principles of skills analysis, to improve the training of dental students in cavity preparation. A combination of psychological and physiological performance measures with movie filming and detailed questionnaires was used to isolate the perceptually difficult skills in the task of cavity preparation. On the basis of this analysis an electro-mechanical simulator was constructed and validated on a sample of dental students. Subjects practising on this simulator were able to perform (without the aid of the simulator and instructor) one-quarter higher quality in one-half shorter time than the subjects in the control, traditional, group (Salvendy *et al,* 1973).

A conceptually similar programme was the application of skills analysis techniques developed on the above project to a surgical task – that of the 'everting square suture' used in plastic surgery. A very successful simulator was developed, Fig. 2, and validated against traditional methods using 36 medical students. This device gave much better quality, training times reduced by about 20% and significantly reduced psychophysiological indices of stress when compared to the traditional training method (Pilitsis, 1975).

With the advent of the increased awareness of industrial safety in the USA, evidenced by the OSHA Acts of 1970, came the need for research not only on accident prevention but on accident research methodology. A unique opportunity existed at SUNY at Buffalo for performance of valid, meaningful research into accidents using the University Ski Club. This is a closed population with well defined skill

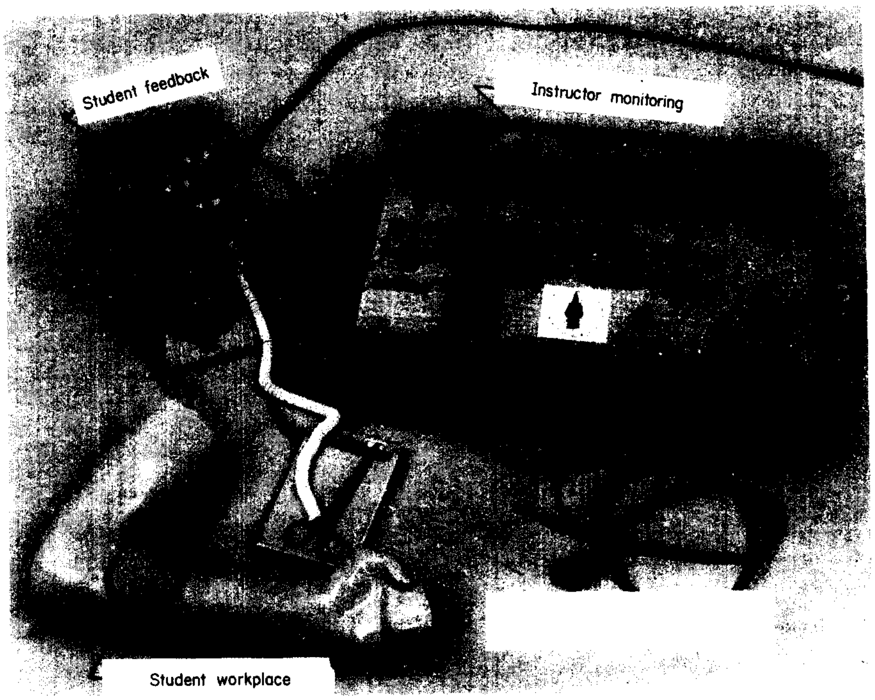

Fig. 2 'Inwound' suture training simulator components

levels and exposure-to-risk information and enough accidents per year for statistical significance! It is important that *all* those who do not have accidents as well as those who do can be studied. The first study (Shealy, Geyer & Hayden, 1972) showed just how important ergonomic factors are in reducing ski injuries. Fig. 3 shows the large difference in accident rates between different types of ski bindings. Using the same methodology the effects of age, sex and skill level of the skier on accident rates was measured. This work is still continuing with the measurement of risk-taking behaviour by the same closed population.

The turnover of staff in the early 1970's resulted in changes in detailed emphasis in the Human Factors effort but not in the overall direction of the department. We still study human skills at work and with largely similar methods (skills analysis, physiological measures, task performance measures, etc) but the types of task studied have broadened.

The health services applications in medicine and dentistry are being followed by application of ergonomics techniques in hospitals and ambulances. A study of a local children's hospital (Drury, Barnes & Daniels, 1975) showed that almost all of the materials handling was done by hand using 57 varieties (!) of wheeled carts, beds, trolleys, and equipment (Fig. 4). The techniques developed earlier for assessing controllability of industrial vehicles were applied to these 'pedestrian operated vehicles' with some interesting findings. Whilst all of the 'vehicles' could physically fit into all of the spaces, many of those frequently used were of such a size and weight that the probability of collision in crowded corridors was large. On the basis of measurements with a range of vehicles and situations, recommendations were made on such divers factors as manning levels, positioning of handles on vehicles, wheel sizes and even selection of floor coverings.

Human Factors assessments of many aspects of emergency medical care are underway following the close ties with the local Regional Medical Program by Warren Thomas and Colin Drury. Projects include evaluation of Paramedic training programmes, a Human Factors analysis of an emergency radio system and the novel idea of applying signal detection theory to emergency medical decision-making (Barnes & Drury, 1975).

In addition to skiing accidents, a source of increasing anxiety to administrators is the explosive increase in bicycle accidents (over 100% pa). A major study is underway by Colin Drury to use Human Factors techniques to develop effective government intervention strategies for the reduction of bicycle accidents. This includes measuring exposure to risk; task- and skills- analysis, law enforcement, bicycle and highway design and training schemes. This study utilizes the skills of another faculty member, Myron Zajkowski, in the area of traffic safety research. Fig. 5 shows part of the research team 'on location'.

Research into the skills in controlling large industrial processes is being conducted along two interlocking lines. The first of these looks at how a human operator detects faults in process output (inspection tasks) and the second studies how an operator integrates this data with process knowledge (manual process control tasks). Results of much of the research done in the inspection area to date at SUNY at Buffalo were presented at the recent International Symposium on Human Factors in Quality Control reported in the December 1974 issue. Locally funded research in the latter area (eg, Drury & Baum, 1974) is focusing on developing measures of process control strategy and performance using laboratory tasks.

Several research projects are also ongoing in the areas of highway safety and environmental impact assessment. M.M. Zajkowski is evaluating the effects of symbology in motorist information systems. In this research, traffic manuals of American, European, and Asian countries have been obtained and are being analyzed in terms of similarities and discrepancies in the use of colour, shape, and symbol coding. Discrepant codes will be used as stimuli to assess the categorical responses elicited from an American population. This research will be replicated with the assistance of

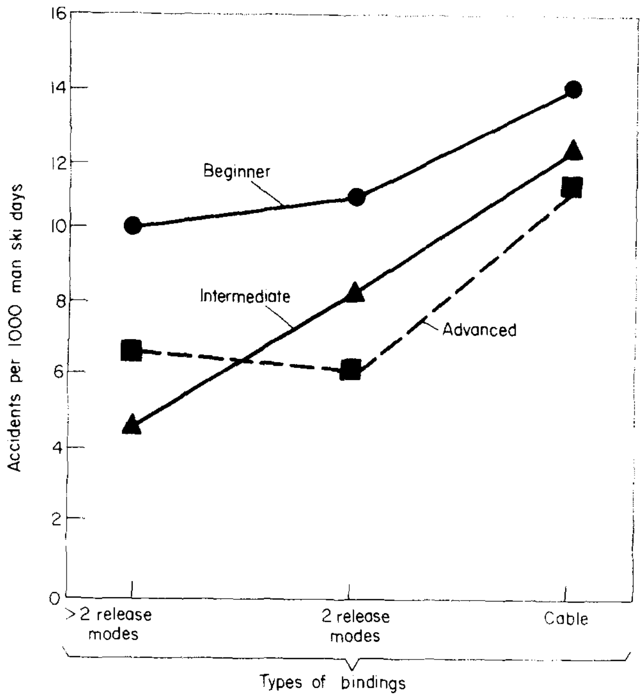

Fig. 3 Accident rates as a function of ski bindings, by skill levels

Fig. 4 Hospital vehicle environment

colleagues in Canada and Europe. This goal is to provide the initial basis for the establishment of warrants and standards for the use of symbolic codes in transportation systems. A research programme is also being developed for the establishment of information systems for intermodal transportation users.

SUNY at Buffalo provides a unique opportunity to develop methodology and instruments for the assessment of the relation between the physical environment and perceptions of that environment. On the new Amherst Campus a residential complex of experimental colleges has been constructed. The Ellicott Complex (see Fig. 6) is a unique architectural structure where students, live, work, and study. The University faculty, offices, and classrooms are also contained in that complex. Thus the facility offers a unique opportunity to conduct a comparative analysis of the attitude about a relatively novel environment with the attitudes about traditional University environment as experienced on the main campus of the University. Measures of group environment, work environment, and study environment will be analyzed and compared with information measures and physical descriptions. Data will be obtained from students, faculty, and visitors and will subsequently be organized according to major demographic variables to show the interrelationship between attitudes, environment and previous history.

The future

The event of prime importance in 1975 will be the commissioning of the new Industrial Engineering building

Fig. 5 Bicycling safety research team 'on location'

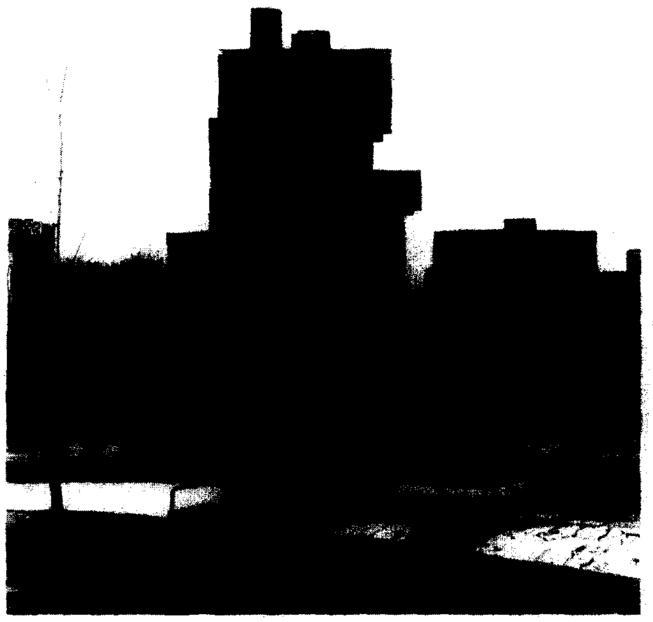

Fig. 6 Ellicott Complex – a new student environment

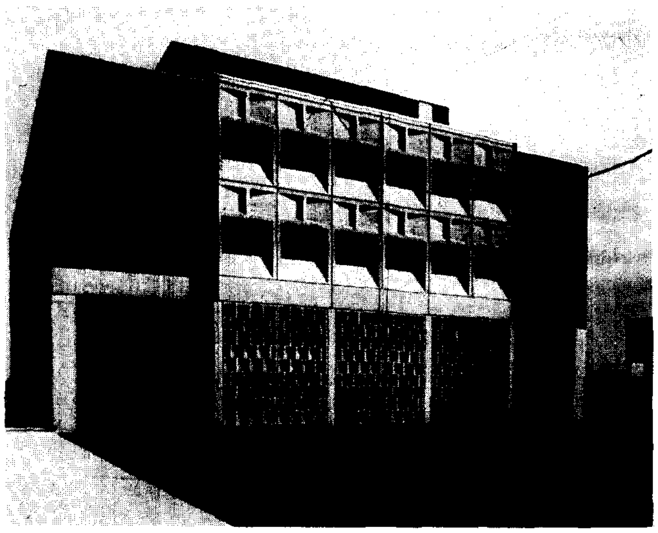

Fig. 7 Lawrence D. Bell Hall – the Industrial Engineering building

(Fig. 7) with its Human Factors laboratory complex. Planning for this has extended over ten years, under a variety of administrations and Human Factors faculty but the thoroughness of the planning process can be seen in the fact that it represents the state-of-the-art in a number of areas.

The heart of the laboratory complex is to be a dedicated real time control minicomputer specified to provide monitoring and control of a variety of instructional and research experimental tasks. In addition to the basic computer (PDP-11/45), the system will include graphics capability, 40+ million words of disk storage, digital/analog – analog/digital conversion, personal storage media for students (DEC-TAPE), and sufficient digital input/output control to handle eight experimental stations simultaneously.

The variety of devices controlled by this facility more than justifies its acquisition. For example, a 1200 ft^3 (34 m^3) environmental chamber with a temperature range of $-20^\circ C$ to $+170^\circ C$ and full humidity range can be controlled on-line together with a whole work-physiology laboratory of treadmills, bicycles and physiological transducers. For information processing skills the basic visual and auditory stimuli can either be generated on-line and presented on CRTs and speaker systems or stored on random-access 35 mm projectors and tape recorders and accessed on-line by the computer system. This makes possible a variety of applications, such as adaptive training systems, where the choice of the next piece of information is contingent upon the subject's previous response pattern.

In addition, computer compatible peripheral equipment has been ordered which will permit the establishment of highly sophisticated laboratory facilities in audiometrics/ psychoacoustics, reaction time, psychomotor skills, control design analysis, and electronics instrumentation. Students will have an opportunity for a hands-on learning experience in a completely modularized Human Factors teaching laboratory.

The ability to simulate very complex situations such as industrial processes or whole factories will enable really valid research programmes focusing on the skilled decision-maker, such as a factory manager and his/her interrelationship with the complex mathematical models of operations research. Industrial Engineering could be reaching the point where it gets back to looking at 'Scientific Management' which is where it started. But this time it will have 50 years of tools and techniques developed to tackle the job.

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