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A description is given of the application of psychology in the man-computer system and in particular of the results of research on operator and programmer utilizable in personnel selection.

Computers are gaining ready access to all the branches of national economy, education, health resort, research, while simultaneously undergoing an intense development of their own technology and programming equipment.

Engineering psychology which deals with adaptation of machines to man and an optimization of their functions in a large system, has thus far brought in only desultory concepts on computer systems. Technological pressure has made it necessary for engineers, mathematicians to concerne themselves with these issues (e.g. cooperation between man and computer in problem solving). This was also caused by the fact that experimental psychology was oriented to laboratory simulation, the results of which could not be applied to real situations.

New aspects have been brought here by systems psychology which definies complex problems of the real world in terms that enable contact with specialized disciplines, or generalization of concepts beyond the frontiers of isolated disciplines [8]. Applied systems psychology represents an integration of concepts of engineering psychology, human factors, training, evaluation of systems. The concept of a personal subsystem has arisen which is proposed and planned in relation to other subsystems of a complex one.

One such system is also that of man-computer. In view of the rapid development of computer technology, research should be aimed at discovering universal principles. Psychological problems connected with computers may be divided into these areas: man-computer interaction (acpects of hardware and software), personnel selection, socio-psychological aspects of computer introduction, adaptation of computer systems users. Some of these aspects will be briefly dealt with here, note being taken of the contemporary state and prospects of development of the computer technique.

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As regards the area of man-computer interface, this is primarily a question of hardware, which admints of application of the known concepts of engineering psychology. This involves an optimization in the disposition of the control panel of the computer (is especially important in the younger computer generation requiring frequent manipulation at the console), choice of a suitable type of equipment for input and output data, overall arrangement of user's' panels (manner of depicting information), the question of codes employed, feed-back information, facilitation of locating breakdowns, etc. The general requirements for size, shape, disposition of displays and controls, design of control panels and operator's position have been described in detail in texts on engineering psychology, and here we only wish to point to some specific requirements.

A comparison of the speed of data transfer by means of various input devices has shown manual writing to be the fastest, typewriting is slower and the slowest is hand printing of letters with spacings. The transition from a handwritten filling in of a form to a keyboard brings about a temporary decline in performance, until practice is gained by training. As regards keyboards performance is double with a 5×5 matrix set than with one of 10×10 set. Erroneousness may be lowered by setting up a reference point for the hand (e.g. a special keyboard for the thumb with the function 0 or +). Integrated input and screen reguire feedback so that the user might have a screen control to see whether computer had accepted the input or whether it is engaged (in real time computing). On the whole, the keyboard is suitable for low speed input of alpha numeric data and according to Nickerson [17], despite a development of graphic inputs, it will remain the basic element in on-line interaction. In problem-oriented languages, programming may be facilitated by means of keyboards in that individual keys will be destined for specialized functions. Data have also been obtained on the suitability of combining keyboards and screen in information transfer. As regards the light pen, its drawbacks lie in its lack of precision (as a result of the necessity of pressing simultaneously also the pressbutton), in the inconvenience of vertical writing and slowness of manipulation. However, its direct positional information, lower demands on programming, and possibility of a dynamic change of data in direct interaction represent definite advantages.

Performance in text punching may be improved by giving priority to words that carry some meaning or such vowel structures that represent phonetic units. Enhanced performance in manual input may be increased mainly by reducing the proportion of auxiliary activities and doing away with the necessity of visual control.

Data output from the computer embraces a wide assortment of equipments. In interaction displays it is advisable to develop continuous variational scales (extension or contraction according to requirements), horizontal screens facilitating writing with light pens, presenting manifold information, etc. In the case of screens, account should be made of whether they are to be used individually or in group, the type

and amount of the information presented, response times required by user, display-control relationship. As regards the legibility of the data, it has been found that a geometrical division of the numeric sequences diminishes the time required for transport. Similarly, grouping of the materials into blocks of 3–4 members enhances transport reliability. Symmetrical grouping seems to be the best.

Marked differences have ben noted in the legibility of types printed by different output systems of computers [3]. Of the compared system, the most legible proved that of DIGI-SET (Siemens 4004), or Courier (IBM typewriter with ballhead types), the worst being the standard computer printer (IBM 7040, or IBM 360/40). The investigation showed the rate of reading to have slowed down by 13 percent, term sorting deteriorated by 12 percent and sign differentiation by 27 percent.

II.

Programming languages entail the need satisfaction of an ever growing and differentiated circle of users, and this is where psychology may be of help with its concepts. The programmer has to exert the greatest effort in analyzing problems and designing algorithms, while the layman encounters the greatest difficulty in writing the schema in the input language. As regards language, communication should be oriented to the problem (information seeking languages, list processing languages); the user should construct his programmes by stages, and language should facilitate search by trial and error. Unfortunately, no criteria of suitability have so far been elaborated: i.e. easy to learn and flexibility of programme languanges. Even though FORTRAN and ALGOL mean a considerable approach to human language, nevertheless, instructions on the basis of specific aims will be required particularly for cooperation in real time. According to Licklider [12], the optimum language for interaction must be the result of cooperation between psychologists, linguists and computer experts. The basis should be a comparison of the languages in use at present, as also the operational and synctactic structures of interaction. A universal language is expected to be a family of dialects (with a common syntax), each of which would be destined for one area of application.

Beginners would make use of the conversational mode, and those proficient in programming of the abbreviated input. The creation of problem-oriented languages has enabled to formulate problems in technical terms of the appropriate branch of science, whereby availability of computers to nonprofessionals has been increased considerably. Further development along this line should be pursued in agreement with concepts on human problem solving and the characteristics of the language used in this area.

III.

The man-computer symbiosis derives from their different abilities and presumes an optimal division of functions between these two components [11]. Man will set goals, ask questions, solve situations with a low probability, fill in gaps in computer programmes. The computer will transform hypotheses into models which it will simulate and verify, evaluate the proposed courses of activity and carry out the routine part of mental work (information retrieval, calculations, graph plotting).

The effectiveness of reciprocal cooperation between man and computer will depend on their adaptation, man's preparedness for this activity, computer accessibility to man, etc. According to Glushkov [7] what will be required of man is a clear task formulation, a knowledge of the computer possibilities (and limitations), the programming language; the computer is expected to possess a great memory store of items, understanding of higher programme languages, rapid and correct answers to user's questions, ability of organizing the computer process.

A different situation in man-computer cooperation ensues with different types of these systems. Here, two opposite trends appear: the user either comes closerto, or further away from the computer (the intermediary is usually the consultant, programmer-analyst). The types of systems differ through the user's, programmer's, consultant's and operator's activity at the various stages of problem solving (familiarization with the task, set up of the plan of solution, its realization, verification of the final solution).

In the case of an on-line connection between user and computer, such questions as the choice of an optimum language, adjustment of input and output devices, computer response time should be dealt with from a psychological aspect (particularly in time sharing systems), these being more effective with work in real time.

In contrast to the customary solution of preformulated problems, or data processing in accordance with predetermined procedures, in the case of dialogue involving man-computer contact, the algorithm evolved in the course of the process, thus achieving faster and easier solution of the problem. During cooperation with a computer, man carries out these typical tasks: questioning, describing the state, diagnosing, panning, selecting alternatives, optimizing, constructing, discovering [15]. The computer expands space for the problem and for the solution and man evaluates this space and contracts it.

A regimen dialogue (conversational interaction) is spoken of when the waiting time for a computer response does not disturb the user's thinking process in problem solving. As a rule, this involves a frequent interchange of brief items. Computer response time should usually be 1–2 secs; with a longer time lapse the user's mental output declines (the limit is 15 secs, when waiting for a response becomes a source of unrest).

The question of response time is of importance particularly in computer systems with time sharing. If response delay is inevitable, it should be such as to permit user to attend to some other task.

Here, in proposing a system, account should be made of the behavioural characteristic of future users, their confidence towards computers [30]. A comparison of the advantages of batch data processing with on-line regimen has shown that time-sharing brings the user closer to the computer and is suitable for problem solving. Processing of data by batch is effective in economic operations.

An area, little surveyed as yet, is cooperation between the technological operator and computer. Certain concepts of a general nature have been formulated in the collection edited by Williams [29]. This involves a change in the traditional functions of the operator, difference of these functions in various systems, principles of operator--computer communication, adjustment of the mode of information feeding, method of training, simplification of algorithms in the process of control as a result of man's participation, etc. Popescu [19], drew attention to the growing significance of numerical information for the operator (a drawback is, however, the impossibility of following up the direction of change of the magnitude). A synthesizing of data on the control process with the aid of tables on the screen unburdens the operator's memory. A continuous follows-up of the technological process, controlled by the computer, is made possible by special dynamic mnemoschemas [20].

IV.

Personnel selection for computer work in this country is carried out only on the basis of an estimate, school record; there is a lack here of a uniform methodological conception and analysis of the demands on the different proffesions under definite conditions. Individual attempts to make use in the selection of tests from abroad (e.g. IBM) have not led to any signal success. In view of the growing demand on the numbers of workers in computer technique (e.g. for the year 1980, the number of operators is estimated to reach 4000, that of programmers being even higher), as also the necessity of a more effective utilization of computer technique, the equstion of personnel selection must be dealt with, also in this country, on a scientific basis.

From foreign literature we know only certain partial, for the most part empirical procedures [16]. This aspect is dealt with in a more complex manner by Miller [14], who has pointed out the applicability of general and special tests to programmer selection. Reports on operator selection are scant. From home studies in this area, mention may be made of those by Kolman [10] and Benešová [1; 2].

The need of a psychological and socio-psychological preparation of a mass introduction of computers in the production and management sphere was the principal guideline in setting up our part project of the State research programme. The psychological aspects of the man-computer system are followed in computing centres where a complex psychological analysis can be carried out. An overall mapping of the items involved was done by means of a questionnaire survey in 43 computer centres in the whole Czechoslovakia (the results are reported elsewhere [26]). Two main

problem areas have come up here; namely, the relationship of the centre to the user, and personnel issues (selection, training, further professional improvement).

Here is a brief job description of the principal professions in a computing centre.

Punch operator transfers information items from the basic data on to the information carrier, using a keyboard similar to that of a typewriter.

The console operator services the computer unit and executes information processing, feeds peripheral units with the required media and material, and in case of need, intervenes in the processing in the interest of a successful termination.

The programmer carries out transformation of instructions and data from the human to the computer language. As a rule, he starts from the block scheme of information processing which is set up either by himself or the programmer – analyst.

The technician helps to install the computer, does maintenance and control work, and repairs breakdowns.

In our research we first analyzed in detail the operator profession of a computer and compared his activity with various types of computers (CDC 3300, MINSK 22, TESLA 270, IBM 360). The greatest difference in the frequency distribution of the various activities of the operator was between manipulation of the computer panel and a follow up of the computer typewriter. Demans on the operator's mental activities are higher with a lower computes generation. It was found that middle school education is sufficient for this type of work, and in the selection, an ability conscientiously to carry out routinely recurring operations, is preferable to an above-the-average intelligence, for with higher aspirations, the latter leads to dissatisfaction with the work and to fluctuation. This aspect has been dealt with in more detail elsewhere [27]. In verifying a battery of psychodiagnostic tests for operator selection, their results were compared with those of a special operator test and rating of work achievement.

The next profession to be studied was that of programmer-analysts insofar as they significantly affect work effectiveness of a computing centre and are an important link between the user and computer. From works published and our questionnaire survey it follows that a successful programmer is of moderately above-average intelligence (abstraction, analysis and synthesis), is neuropsychically stable, precise, persevering and sufficiently sociable. In order to make a deeper analysis of the demands on the mental faculties of a programmer – analyst, in the first stage we undertook an investigation of 78 programmers (from 3 computing centres and a training course for programmers) using current testing methods, and also a special battery of foreign tests for programmers (CPAB).

The results [28] showed that a successful programmer appears to be characterized mainly by an ability at abstraction and practical mathematical thinking, but important traits here are also judgement (discernment), comprehension of relations and inductive verbal thinking. Among personality traits, those of friendliness, emotional stability, self-assurance, realism, a calm strong will predominate. Rating of their work achievement shows their quality of work, a creative approach, and consistency to be in the foreground.

Similar data were also obtained by Pitariu [18]. His test battery had an overall validity of $r = 0{\cdot}686$. Successful programmers were noted for their equanimity, perseverance, inner dynamism and ability to make considerable intellectual effort.

The second stage of our survey was given to a time analysis of programmer activity, and in the third, using the technique of critical incident we endeavour to ascertain the most serious difficulties and problems that a programmer is likely to encounter in his work.

In addition to the study of individual professions, a socio-economic survey is also being carried out in certain departments of computing centres (punch operators, programmers, see [4; 5]).

In future, it will be important to devote attention also to an analysis of the training system of prospective workers and to aspects of motivation in connection with their further professional growth.

V.

Questions of adaptation of users of computer systems are acquiring great significance principally in view of large information retrieval and management systems being set up (whether at plant or superplant levels), where man is still an important component. Experience in this respect, mainly from abroad, points to a considerable impact of negative attitudes towards such a system and its operation. Hence, it is necessary already at the conceptual stage of the introduction of computer systems to take into account the psychological and social aspects of the problem. Alongside the technical, economic and organizational preparation, it also imports to carry out a psychological analysis of the corresponding terrain, and on this basis both to determine the orientation of the psychological impact on the plant and extramural sphere (a question of creating favourable attitudes), and also optimally to incorporate the information computer system into the social system of the plant (organization).

Available experience goes to show that unfavourable attitudes towards computers derive from a popularization of faulty performances by computers, a necessity of a change of the working style by leading workers (especially on the middle level of management), or working procedurres in the rank and file of workers, fear from a decrease of working opportunities, etc. From psychological research we know that man has a relatively stable and fixed system of attitudes towards the fundamental phenomena of his human and working environment. In trying to alter these attitudes, it should be borne in mind that people are not interested in information that is in contradiction to their attitudes. It is best to affect attitudes through a working group, for an individual sets great store by his position, recognition, prestige, and doest not wish to go counter to attitudes accepted by a whole group. A change of attitude is more easily achieved in those who have not as yet acquired extreme standpoints and firmly determined attitudes. Attitude analyses and targeted interviews will enable group dynamism, essential motivation sources to be determined. Plans should

be made well in advance concerning the use of suitable means of informational influencing, and organizational measures. It is especially urgent to explain the advantages of the system to be introduced to those responsible for its successful operation. Familiarization of the leading personnel and the other exployees with the aims and priorities of the system will help achieve an indentification of the people with the project. An orienting survey along these lines has been carried out over here by Brožová [4; 5] in connection with the introduction of an integrated information system to a hospital.

VI.

A mass introduction of computers carries with it also wider social implications, an influencing of human society. Even though under our conditions we need not expect identical phenomena with those seen in other socio-economic conditions it is nonetheless evident, that in the very near future, computers will affect various spheres of our lives (changes in teaching systems, dissappearance of certain avocations, availability of information from large data banks). According to Martin and Norman [13] the transition to a fully computing society is similar to the breaking through the sound barrier. A slowing down of development will be brought about by the inability of present – day institutions to react promptly enough to the changes (this refers especially to the schools). Social disruptions will ensue chiefly as a consequence of a low adaptability of people, hence, precisely because of this, attention shall have to be devoted to an acceleration of this adaptability in the general public (changes of computers in public administration, easy accessibility to a large amount of information, new methods of training with the use of computers).

VII.

In conclusion, it behaves to underline that the introduction of computer techniques will be effective only if people are adequately prepared to exploit them.

Hence, projects should embrace not only the computer technique, but also the corresponding human activity, the human component in the man-computer system. From this there follows – as mentioned by Glushkov [7] – the necessity of a complex research into problems of mutual activity between man and computer. Here, psychology must keep step with the development in computers and this principally in the area of new peripheral accessories, means of programming and utilization in new areas (heuristics).

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