A man-machine principle applied to human behavioural tests

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The subject of our paper is to draw up a principle of a special man-machine relation and the examination of conclusions originating in this principle, as well as of consequences emerging during the practical realization.

In this system there is an automaton with a relatively great degree of autonomy, a capacity of decision making, interposed by the cognitive subject into the process of cognition, and in this manner a connection is established between the automaton and certain mechanisms of the system to be studied which is a human being. This automatic cognitive system intervenes in the activity of the subject investigated, makes a diagnosis of the state of the system by analysing the responses received.

The special nature of a connection of this type between man and machine has appeared in a few psychological testing methods, and in certain systems consisting of a human operator and a machine suitable to realize some kind of adaptation. We outline the application of this principle by one of the most frequently used psychophysiological investigations, the reaction-time (*RT*) measurements. One of the peculiarities to be stressed here is: since the person is given a light stimulus and his response is only to press a button, the man-machine conversation occurs through a very *narrow* information channel. In spite of this we are trying to make use out of this connection as much as possible.

Here we are aimed essentially at giving a review of experiences gained in the first phase of the realization of such a cognitive system. Dealing with systems of this type experimentally a twofold benefit is expected:

1. It accelerates the process of recognition of certain biological (in our case psychophysiological) processes.

2. It makes possible to study the partial laws of certain human cognitive processes themselves — due to the cybernetical approach applied — independently of the system just studied.

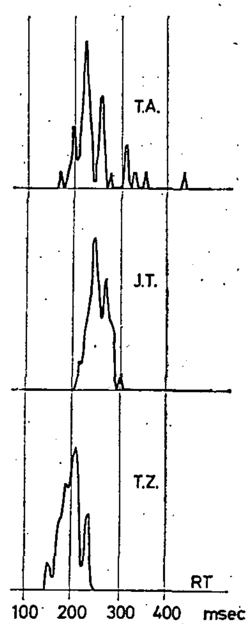

Fig. 1. Distribution of reaction-time values of three persons on the same stimulus structure

The system, to be investigated by applying the principle mentioned above was a kind of human behaviour, in connection of which we have had direct experimental results, performing psychophysiological research of numerous behavioural forms. We suggest to use the term *RT*-behaviour, and we are going to illustrate the practical application of this particular man-machine principle outlined above with the help of a cybernetical system suitable for analysing this behavioural form.

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First of all we are going to explain what is to be called reaction-time behaviour, or more precisely what is the reason to speak of it as a physiological category.

The human optomotoric RT is generally regarded as a product of a simple delay unit, and the sequence of responses evoked by stimulus sequences is characterized by statistical parameters (mean, standard deviation etc.). In our experiments we tried to go further by applying non-traditional evaluation methods.

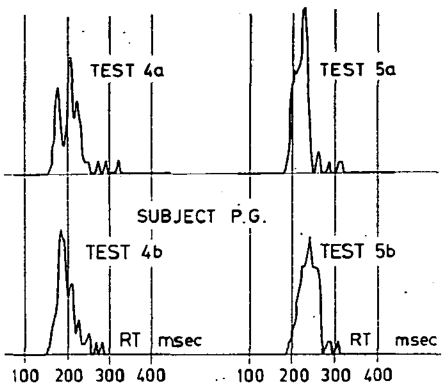

Fig. 2. Distribution of reaction-time values obtained from the same person on the same day. In the test versions *a* and *b* the interstimulus intervals were produced by a random generator of the same parameters.

The rhythmical stimulus structures applied previously — in spite of being easily produced — turned out to have some obvious misadvantages. Due to the recognition and habitude of rhythm, a phenomenon of rhythm-following appears, consequently one response cannot be considered to belong to the preceding stimulus any more.

This failure is eliminated by applying pseudo-random stimulus sequences presented by the experimenter himself. In the most up-to-date method at present the basic structure of stimuli is produced by the random generator of a computer. In certain cases, we modified the basic random structure by interposing short sequences of fixed intervals.

Various stimulus sequences consisting of 64 or 128 interstimulus intervals were available on punch tapes, and were fed into a special-purpose computer (NTA 512), which gave red light flash stimuli to the subject. (The light stimulus ceased only when the subject reacted with pushing a button. Hence, he could estimate his performance more or less precisely.) The reaction-time values were measured, stored and then displayed, or registrated in punch tape for further analysis.

A small but psychophysiologically well examined group was investigated for a long time using various stimulus structures.

Our aim in evaluating the results has been from the beginning to be able to classify the individuals according to their *psychophysiological types* and *actual states.* In connection with this it soon turned out that if only traditionally accepted statistical methods were applied, the types and states could be separated only by comparing with the results of other psychophysiological tests — if it was possible at all. Therefore we examined the distribution of RT values in which significant various shapes were found indicating the individual differences (Fig. 1).

Naturally the statistical parameters (mean, deviation, greatest occurence etc.) can be illustrated by these histograms.

It can be seen, however, that the shapes of histograms greatly depend on the interval structure applied in the tests.

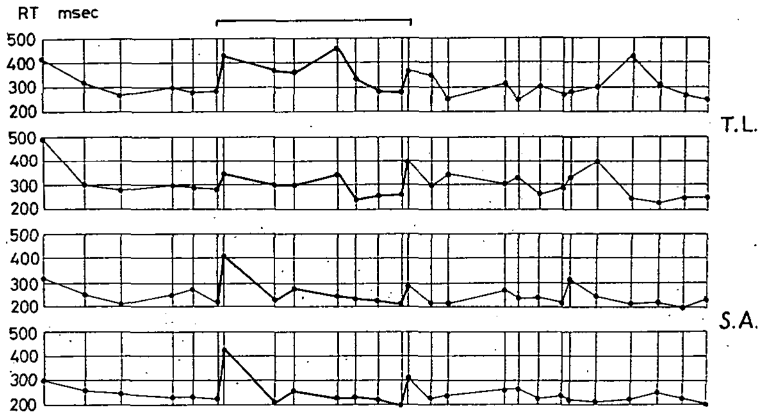

Fig. 3. Reaction-time sequences on the same test structure. The first and second curves were obtained from the same person in the morning and in the evening, respectively. The third and the fourth ones are from an other person and are paired similarly. In the marked phase the permanence of individual response patterns is well shown.

It was surprising to find strongly different histograms (Fig. 2) registrated from the same person on the same day, in response to two stimulus sequences of a random generator with *same* parameters. This phenomenon turned our attention to the fact that the shapes of histograms depends less on the statistical characteristics of stimulus structures, but more on the *context* of preceding stimuli. Naturally, it means at the same time that when examining the context-dependence of each RT value, it is not sufficient to take into account the dependence on one preceding interstimulus interval only, since the interval distribution of random stimulus structures with the same parameters can be considered to be equal (in the case of sufficiently great number of samples). Consequently in the two test versions the same response-distribution should be received.

We examined the dependence of RT values on the *one* preceding interval, and we found slight correlation in the case of very short (200—500 msec) intervals only.

After this there was only one way left to analyse the reaction-time sequences: *to analyse them as sequences*, i.e. time processes. During this examination a particular attention was paid to responses evoked by certain stimulus patterns consisting of 2—10 stimuli. These responses, because of their peculiarity, can be called as "response patterns". It was observed that the same persons on different days — occasionally in different physiological or psychical state — produced characteristic individual response patterns.

In the Fig. 3 the first and the second curves represent the response of the same person on the same test structure in the morning and in the evening, respectively, the third and fourth curve show the similarly connected results of another person.

Analysing the patterns it turned out that their individual-determination is of greater degree than that of their distribution not reflecting time processes. An analysis on the basis of time processes — though it is more difficult — provides also more information.

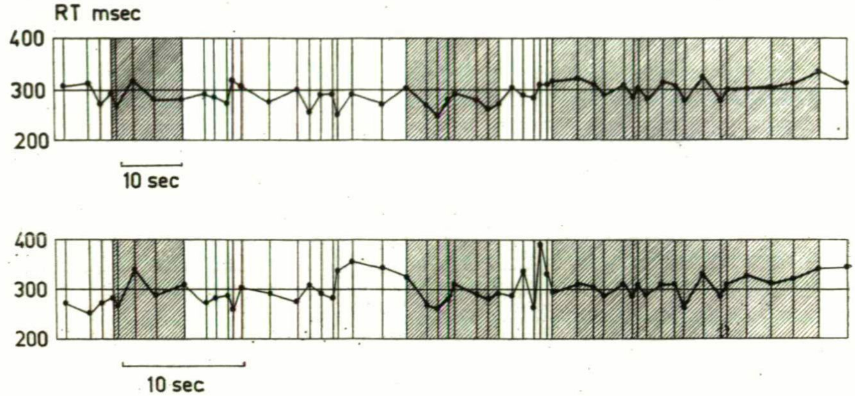

Fig. 4. Reaction-time sequences obtained from the same person. In the second case each interstimulus interval of the test structure was restricted to the half. Note the similarity of the RT sequences in the lined sections.

It was reasonable to try to give an explanation of the phenomenon in the following way: during the test the sequences of stimuli of the same intensity, or on the other hand the sequences of intervals between them constitute the environmental changes for the person examined. The person or more precisely his complex of mechanisms taking part in producing responses — while his state is being changed— will produce his response. The response can be conceived as context-dependent if the context is constituted by *the complex of stimuli and the preceding responses.* On the other hand, the response patterns can be regarded *behavioural patterns* to the environmental changes. It is reasonable to state that human beings show a particular *RT-behaviour* under these experimental conditions. Furthermore, we supposed that the RT-behaviour explained in this way is a component of the human individual behaviour as a whole, consequently it is characteristic for the structure of his nervous system.

This behavioural conception of RT-patterns being one of the starting points of our work, is strongly supported by our observation illustrated in Fig. 4.

The curves are from the same person, in the second case each interstimulus interval (ISI) was restricted to the half. (For an easier comparison the scales are different). In spite of this in the two curves we can find three sections with almost the same shape, amounting approximately 50% of the test. This finding supports, on the other hand, our previous statement that a RT-value cannot be explained only on the basis of the *one* previous ISI value.

A question arises: how is it possible to recognize the typological class and actual state of the person examined from the RT-behavioural investigation. To determine the behavioural signs mentioned above a great number of stimulus patterns should be employed.

The application of certain stimulus patterns to a given person can be fruitful if the person reacts to them in a sensitive way, but at the same time an other person — just because of his different reaction type — eventually provides non-informative,

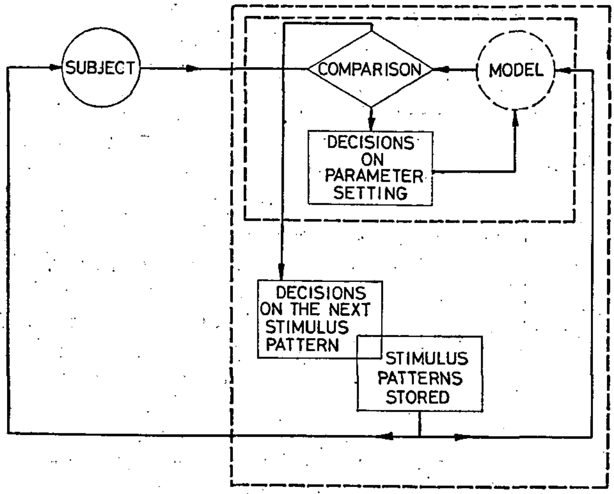

Fig. 5. Simplified block diagram of a man-machine system for psychophysiological testing. For explanation see text.

non-characteristic responses only. It is easy to see that during further examinations with two persons, stimulus patterns of different types should be used. Hence, in the cognition of RT-behaviour — like every other cognitive process — we should pass through the stages of *preliminary hypothesis — experiments — modified hypothesis — control, etc.* periodically repeated. This process takes a lot of time, the cognitive subject's judgement and decision is slow (in comparison with the speed of information concerning behavioural signs) and finally, the duration of an experiment is limited.

These considerations constitute the basis of the experimental setup in which a particular man-machine relation mentioned in the introduction can be realized. One of the peculiarities of this system is — as it performs the mechanization of a phase of the human cognitive process — to include by all means a functional model of the object examined.

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Fig. 5 illustrates a schematic, simplified block diagram of the system consisting of a person investigated and a computer. The major functions of the subsystem to be realized by the computer are:

1. Comparison of response patterns of the subject and of the functional model to the same stimulus pattern, on the basis of similarity criteria.

2. Suppose that after examining the possible model variations i.e. possible parameter-constellations the similarity criterion is satisfied by several sets of parameter values. Therefore, they are to be stored representing diagnostical alternatives at the present stage of investigation.

Then, the corresponding parameters of the same value in the different sets satisfying the similarity criteria must be searched in order to leave them out of consideration i.e. to fix their value during the further investigation. Hence, the necessary number of model versions to be examined at the next stimulus patterns can be reduced step by step.

3. After establishing the "proper" sets of parameter values the next operation is to choose one out of the stimulus patterns stored, depending on the previous responses i.e. on the model parameters of *greatest uncertainty.* This requires to classify patterns from the point of view of several parameters to be determined. Consequently, an extensive, off-line model investigation is to be done in order to compile a parameter-oriented set of stimulus patterns.

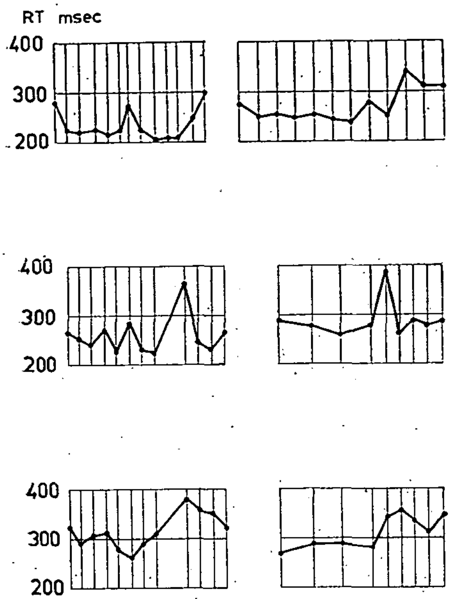

Fig. 6. Behavioural patterns in reaction-time sequences. 1) slow fluctuations in RT performance indicating energetic processes, 2) "surprise effect": a mistake followed by successful corrections presumably owing to high motivation and good energetic economy, 3) "surprise effect" followed by slow corrections.

The steps sketched above form a cycle of cognition, which is likely the same in some human cognitive processes. Each cycle produces sets of parameter values, in other terms, they are points in an n-dimensional space of parameters. It is expected that after some cycle these points will be placed in the space of parameters within a domain well representing the person's psychophysiological type and actual state. Also, if the existing psychological and physiological categories for types and states can be expressed by the language of model parameters i.e. boundaries can be formed in the parameter space, then, using suitable classification methods the diagnosis will be made.

According to this concept, the realization of such a system started with constructing the model of human RT-behaviour. The model experiments — accompanied by further human experiments, of course — are expected to suggest principles of formulization of the cognition strategy, of similarity criteria, and of selecting stimulus patterns into an appropriate parameter-oriented pattern system.

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The major part of physiological mechanisms integrated in the human RT-behaviour is supposed to be of neuronal (nervous) character. A minor contribution is thought to be added by biochemical, hormonal, biophysical (muscular) factors. In spite of this, a neuronal-network type model based upon formal neurons, or upon their recently developed, more sophisticated forms, behaving like randomly connected, moving-threshold elements — could not be applied. This was because — as usually occurs in biological systems — neither the number of the elementary functional elements, nor the exact form and nature of relations connecting them, as well as the transfer functions realized by the subsystems were correctly known. What remained was the way of constructing working hypotheses about the most probable physiological and psychological mechanisms that interact according to general psychophysiological laws more or less proved, thus forming a unique system of the human behavioural mode to be studied.

In Fig. 6 several physiological examples of behavioural patterns are shown in attempt to illustrate the way of our thinking we followed in constructing functional analogies of the rules presumably manifested.

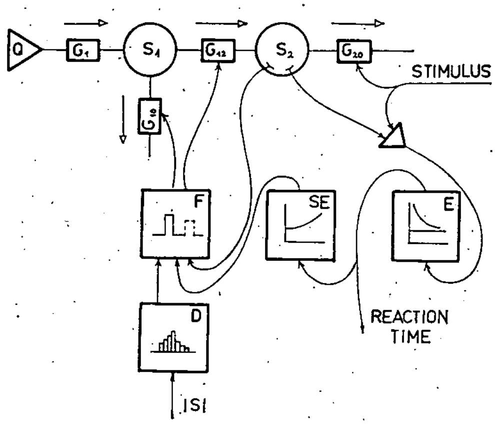

Fig. 7. Block diagram of the model of RT-behaviour. For explanation see text.

The first response patterns on the figure was a very common finding in numerous tests produced by almost all persons if a randomly distributed but nearly isorhythmical stimulation is presented. The wave-like shape of the contour line suggested the existence of at least two basic mechanisms to be considered: a more or less correct *estimation* of the distribution of interstimulus intervals and the *energy-dependence* of some psychological activities not correctly known at yet.

The second pattern is a particular type of response, occuring with a considerable variability, but preserving its general character in all the tests, where a firmly settled signal distribution is suddenly followed by an interval surprisingly different from the preceding ones. Considering its peculiar shape, the idea about an estimator that functions according to some kind of probabilistic logic, seems to be more validated, and further on, this estimating-mechanism presents itself to be governed by a *correcting* mechanism too, which must be activated whenever the person deviates from a mean performance, i.e. an *error detecting* function can also be supposed. If the executive part of the system, (the energy-dependent subsystems) is well fitted to the task and the estimators are working properly too, then a very successful corrective step will be performed, as seen in the 2. patterns. But if the person is more tired, or the economy of the energetic chain is disturbed by other reasons, the correcting step induced by a mistake cannot be so successful. (See patterns No. 3.) A further assumption emerging from the facts and relations mentioned above was the following: the psychophysiological activity requiring some kind of energy would be the *focusing of attention* to a specific task, or in neurophysiological terms the concentrating of excitation upon a central nervous system area surrounded by some specific sort of lateral inhibition. This area seems more likely to be the sensorimotor cerebral cortex; thus the specific excitation-inhibition pattern impinged upon it will determine the synchronity of nervous cell's firing, which, in turn results in the absolute value of the reaction-time. This latter assumption is strenghtened also by introspective observations, according to which voluntary focusing of the attention to one's *manual activity* rather than to that of stimulus perceiving — considerably shortens the reaction time. It is also an introspection that plays a considerable role in detecting such *feedbacks* which for example, are activated by a sudden or even continuous involuntary fall of the *specific* attention level.

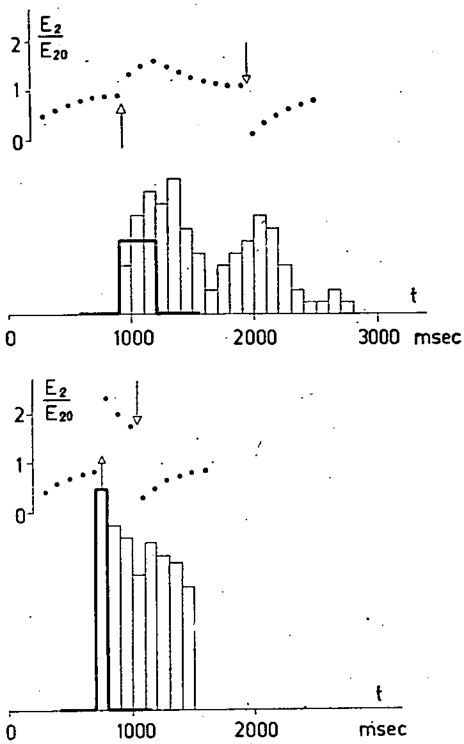

Fig. 8. Generation of "focusing" impulses based on wide (above) and narrow (below) distribution of the preceding interstimulus intervals. Thick lines indicate the position, width and height of the focusing impulse. Dotted lines represent the specific attention level (E_2) related to its resting (unfocused) value (E_{20}). Due to the focusing, E_2 suddenly rises, and then falls almost to zero, when the stimulus appears.

After having analysed a great variety of such RT-patterns it became clear that all mechanisms supposed to take part in generating them, can hardly be kept in mind at the same time. Therefore, we tried to describe these mechanisms, i.e. to formulise a model of the mechanisms supposingly involved in RT-pattern generation. Every mechanism seemed to have two aspects of its functioning: one is the information processing, the other is the operating as an energetical system of finite capacity. As a matter of fact, these functions are closely connected to each other, still, we separated the whole model of mechanisms into two parts. A subsystem of energy distribution is responsible for maintaining an energy level necessary to perform the task. This subsystem is controlled by the other part of the model in many ways.

Obviously, the present model does not include all considerations we make when trying to explain a pattern qualitatively. Its task is now only to decide whether this concept of energy distribution and information processing is sufficient or not for presenting basic properties of human RT-behaviour.

Fig. 7 shows the simplified block diagram of the model. The energy distribution system consisting of the energy source Q, energy stores S_1 and S_2, energy channels G_1, G_{10}, G_{12}, G_{20} can well be illustrated by electrical or hydrodynamical analogies. The energy level of S_1 corresponds to an unspecific attention level supplied by Q and consumed through the channels G_{10} and G_{12}. S_2 stores *specific* energy of attention, its content is then regarded to be available for actions in RT-tests, and is consumed through the channel G_{20} almost entirely when a response occurs. The increase of the transfer capacity of G_{12} (which is occasionally accompanied by the simultaneous restriction of the channel G_{10} representing the *aspecific* drainage of energy) causes a transient increase of the specific attention level in S_2. This process occurs when a "focusing" instruction comes from the other part of the model.

This instruction delivered by the focusing unit F can be produced in two different ways: *1.* on the basis of the distribution of the preceding interstimulus intervals stored in D, and *2.* by observing that the level of S_2 falls to a certain threshold. This feedback-evoked focusing occurs when the stimulus did not arrive by the time expected on the basis of the ISI distribution and the level of specific attention slowly decreases.

In the focusing process the subjectively estimated value of the preceding response plays a very important role. Here the motivation level of the subject examined is thoroughly involved. The "self-estimation" SE realizes in the present model yet a simple relationship between the preceding response and the weight factor produced for the focusing impulses.

The characteristic of the "executive" unit E shows our assumption concerning an inverse relationship between the reaction-time value and the actual specific attention level.

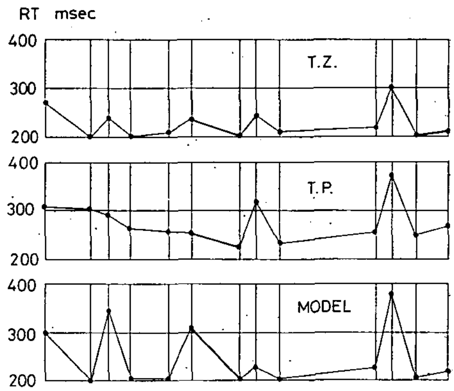

Fig. 9. Reaction time sequences obtained from two persons and from the model on the same stimulus structure.

As an example, Fig. 8 shows qualitatively how focusing impulses are generated and furthermore, how the specific attention level is affected by the distribution of preceding ISI values. Nevertheless, it is to be stressed here that the weight factor for a newcoming ISI depends not only on its relation to the former distribution but also on the fact that shorter ISI values are naturally of greater importance than the longer ones (namely in case of unexpected long intervals one can rely upon feedback mechanisms maintaining a high, but fluctuating attention level for a reasonable time. Naturally, since the most intellectual part of the model is concerned here, beside the processes learning and forgetting, habituation and dehabituation, certain emotional weighting functions indicated probably by the reaction-times themselves should be taken into consideration.

In this initial stage of work we were seeking for those approximative ranges of model parameters within which the RT-behaviour of some individuals in our experimental group could be simulated. Other than stated a good similarity between model-generated and human patterns, the analysis of time processes in the corresponding patterns supported our basic hypothesis according to which there are two characteristic functions closely coordinated in reaction-time generation: an activity like *information processing* and its *energetic conditions*.

In Fig. 9 the upper two curves were registrated from two different persons, while the third is a model-generated pattern. In the initial phase a considerable difference can be seen between each pattern, showing the better energetic economy and estimating functions of the first subject. In the second phase, however, the courses of the reaction-time values are of uniform character.

Fig. 10 illustrates response patterns of two persons and of the corresponding model versions, to an other stimulus pattern. Both versions have estimating and focusing parameters of same values, and in the second case the energy levels are only slightly higher than that in the first one. In the second case, in turn, there were higher focusing impulses produced, as a result of a more intensive self-estimation i.e. of a greater effort to shorten the reaction-time after a long one. Consequently, the only difference between the two person's RT-behaviour was — according to the model experiments — the higher motivation level of the second person.

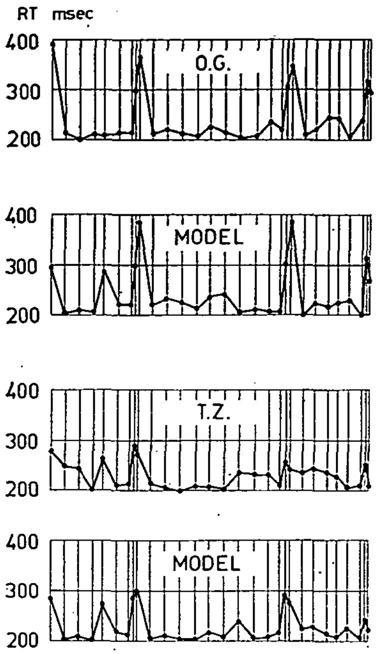

Fig. 10. Reaction-time sequences from two persons and from their model versions.

According to our final task the model of RT-behaviour, being a subsystem of the complex cognitive system, needs a further development in a rather unusual direction. It is due to the fact that among the subjects of our experimental group there was a separated RT-behavioural class of the persons whose patterns could be simulated by the present structure with best fidelity.

This class consisted of two persons, a professional pilot and a racing driver.

The conclusion is that in developing the model an energetic chain of *worse economy* governed by a *less precise information system* probably of stochastic nature as well, is required.

Принципы человеко—машиной системы применительно к тестам поведения

Авторами предлагается методика проведения психофизиологических процессов обследования, обеспечивающая минимальную потерю информации. Для увеличения эффективности обследований составляется индивидуально для каждого пациента структура раздражений в зависимости от его предыдущих ответов. При этом требуется высокая скорость обработки информации о реакции обследуемого пациента и, следовательно, включение в разрабатываемую систему быстродействующей ЦВМ.

Возможность и целесообразность реализации такой системы иллюстрируется на примере исследования оптико — моторного времени реакции. На первом этапе необходимо разработать модель реакции поведения. В рассматриваемой человеко — машинной системе человек является объектом управления (познания), а управляющим звеном — вычислительная машина, определяющая виды раздражений и оценивающая ответы.

Проведенные экспериментальные исследования показали возможность предложенного подхода и адекватность полученных результатов сформулированной гипотезе.

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