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COGNITIVE PSYCHOLOGY AND ARTIFICIAL INTELLIGENCE

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To improve cooperation between psychology of thinking and artificial intelligence, it could be useful to elucidate the present theoretical approaches to thinking. The latter have also been affected by cybernetics and computer science (informational approaches, problem space, heuristics computer simulation, frames and scripts). More recently, cognitive psychology has become crystallized, concentrating on complex cognitive systems. Within its framework considerable attention is now being devoted to mental representation, which is the object of our investigation. Cooperation between psychology and artificial intelligence contributes to reveal specific mechanism of cognition and to promote further development of the theory of artificial intelligence and its practical application.

Following a period of heated controversies between those advocating that thinking is a faculty exclusively proper to man, on the one hand, and adherents of a cybernetic reductionism, on the other, a genuine search has been initiated over the past decade for a common language on the interface psychology of thinking/artificial intelligence. An impetus to this came particularly from the practical need of setting up complex systems involving a symbiosis of human and technical elements. On the psychology's side, this was prompted mainly by the development of cognitive psychology.

1. HUMAN THINKING

It is generally being admitted that psychology of thinking has lagged behind in its development. This may be the result of considerable methodological difficulties facing research in this domain, but may also be due to a varying interpretation of thinking within diverse theoretical conceptions. Psychology in North America has concentrated mainly on behaviorism which derives thinking from the scheme "stimulus-response" as the basic unit of behaviour, laying emphasis on directly observable phenomena. Image is considered as a form of implicit behaviour and stress is laid on the peripheral mechanisms of thinking. Neobehaviourism in turn, investigat-

es relations between reinforcement and activation, with cognitive component being related to the background. Although behaviourism has stimulated extensive research in the domain of learning, an application of these metodological approaches to thinking has proved barren.

One of the nativistic theories is Gestalt psychology [1] which defined the problem situation and method. However, a task is here considered as something extraneous in relation to an individual's thinking: it is not taken as being involved in the conditions of man's activity. Here stress is laid on a new arrangement of the structure of relations in a given problem situation (a perceptual reorganization of the problem) which takes place in virtue of an immediate outlook, shape, form. A study of problem solving makes use in particular of the method of thinking aloud.

A significant contribution to the psychology of thinking has been the work by Piaget [2] who considered units of the cognitive structure – schemas – as products of an assimilating and accomodating contact with the environment in time. The schema is an internalized representation of a class of similar activities permitting a thinking experiment (operation on representations of reality). According to Piaget, the essence of thinking does not reside in a representation of stimuli, but in a "internalized" manipulation of the object. The internal mechanism of construing (within known stages: sensorimotor schemas, concrete operations and formal operations) represents in fact a process tending to achieve an adaptive equilibrium in terms of self-regulation.

A further contribution that might be mentioned here is that by Bruner [3] who holds that the basis of thinking processes is a selection and verification of hypotheses. This involves forms of cognitive regulation of external behaviour: they are considered to be primitive facts. Brunner's contribution to concept learning is generally recognized, particularly his analysis of the subject's strategies (focusing, scanning, conservative focusing, wholist focusing). In this view, the key to an understanding of cognitive development are representations. He distinguishes three modes of representation: with acting – motor principle, is related to enactive representation, then follows the iconic (picture) representation and lastly the symbolic representation. In Soviet psychology the best known conception of thinking is that enunciated by Rubinshteyn [4], especially his observation on the effect of external causes through the intermediary of internal conditions (psychic properties, states, processes). Cognitive processes connot be explained solely on the basis of internal subjective conditions, nor are they merely a function of the external situation. This involves an elaboration of the principle of determinism. The author has further characterized analysis through synthesis as being the fundamental mechanism of thinking activity.

Among the most recent approaches to the analysis of thinking in Soviet psychology is Zinchenko's [5] microstructural analysis of cognitive processes. Some of the prevailing theories on thinking – Dodd and Bourne [6] differentiate those of the information processing theory, Piaget's theory and the nativistic theory – lay emphasis on the schema, the internal structure, a hierarchical description. Thinking

is considered to be a process or mechanism controlling behaviour. One of the drawbacks, however, is the considerable distance between empirical research and theory.

Thinking is today characteristically considered as the highest degree of cognitive processes and in narrower terms is made to include concept forming and acquisition, problem solving and judging. A rather narrow, operationalist point of view becomes manifest in an identification of thinking with problem solving: as a matter of fact, thinking is needed also in formulating tasks, elucidating new problems, acquiring concepts, understanding a text in reading, etc.

One may subscribe to Brushlinsky's [7, p. 52] view that "thinking is inseparably connected with language social process of an independent searching for and discovering of something essentially new, i.e. a mediated and generalized reflection of reality during the course of its analysis and synthesis, formed on the basis of practical activity from a sensory knowledge and far exceeding its borders".

2. EFFECT OF CYBERNETICS, COMPUTER SCIENCE ON PSYCHOLOGY OF THINKING

New approaches to research of thinking have been considerably affected by cybernetics and more recently by its latest discipline – artificial intelligence. Even though they have not become a miraculous instrument for explaining human thinking-psychology of thinking is, however, indebted to them for decisive impulse and a revival of interest in its theory. Reference shall here be made to some major contribution only.

As regards to information theory, it has roused interest in semantic information, in a probabilistic characteristic of the structure of a task, in duration of problem solving, algorithmic thinking processes, in the task of subjective probability or reduction of uncertainty, in information acquisition, etc. These issues were dealt in more detail in our monograph [8]. A considerable contribution in the domain of theoretical conceptions of thinking has been made by Klix and his team. In his latest comprehensive monograph [9] he considers psychic processes as well as thinking to be essentially a process of information exchange between man and the environment. He makes out three classes of problem situation:

a) The initial state is given, possible or accessible transformations are known, and the required final state is to be found (e.g. chess);
b) The final state is given, the transformations are known, and it is necessary to determine as to from what initial state can the final state be deduced (e.g. physico-chemical analysis);
c) Both the initial and the final states are given and such transformations (rules) are sought that permit the transformation from one state to the other (e.g. construction tasks).

The author presents a detailed analysis of the structure and elements of problem

space in which the solution is sought. If the solution is outside it, the problem space has first to be enlarged. Heuristic aspects are also applied in the search, i.e. rules for transforming the states of the problem; they are abstracted from the set of problem situations and may be applied to classes of problems. Klix analyzes the effect of heuristic strategies on the example of the Hanoi tower. Nevertheless, when analyzing problem solutions, one may not confine oneself purely to structural aspects, but has to take into account also the effect of semantics.

Dörner [10, 11] assumes two levels in the structure of the human cognitive apparatus: a data base (epistemic structure) and conscious thinking (heuristic structure), both of which are memory structures. Processes of conscious thinking may be described as stages in information processing. The predominant part of our behaviour is controlled solely by the epistemic structures (reproductive thinking). The heuristic structure comprises a construction of unknown transformations (heuristics), a set of plans and their organization in memory. In addition, the author also points to a possibility of developing abilities to solve problems. In the epistemic structure, production of complexes, their disintegration, creation of macro-operators may improve. Improvement of the overall strategy implies influencing of the heuristic structure.

An emphasis on hypotheses in the thinking processes may be noted in works by Groner [12] who wants to extend the existing models of hypotheses to problems of organization (from a series of paired data one has to construct a rank order of elements – e.g. Peter is taller than Paul. Paul is smaller than John ... Which of them is the taller?). From among the familiar approaches in this domain he mentions computer simulation, propositional models, formalization with the aid of logic, algebra and the theory of automata, as also probabilistic models. He also defines the basic concepts of the general theory of hypotheses.

Besides syntheses of thinking models with the aid of computer stimulation, we also find here efforts at isolation elementary mental operations [13]. These may then be divided on the basis of the dimension of speciality (according to the range of the tasks to which they are connected, we distinguish specific and general operations) and dynamics (variability during a given task – hence, permanent and temporary). Thus we obtain structure (specific and permanent). sign (general and permanent), strategy (specific and temporary) and state (general and temporary).

The investigation of heuristics (particulary of heuristic programming) has exerted a considerable influence on research in psychology of thinking: there came a definite turning away from static laboratory situations (until then current in general psychology), leading towards an analysis of the thinking processes taking place in the solution of complex problems of a realistic nature. Newell and Simon [14] hold that complex thinking processes are built up out of elementary processes present in symbol manipulation, and predicate GPS as the basis of a theory of human problem solving, although they are aware that GPS do not simulate all the aspects of man's behaviour. A further programme for simulating thinking is the system known as

ARGUS [15] which is based on a network of semantic elements and sequential control. Several cognitive processes here take place simultaneously and information structure become altered.

Psychological concepts are closely related to the frames theory [16] investigating the data structure for portraying a stereotype situation and completing it with specific data. This takes contact with a psychological understanding of schema or knowledge units (Bartlett, Piaget).

A feature recently much in vogue in psychology is a processing of the script concept [17]. This involves a cognitive structure portraying a stereotype sequence of events (usually from daily life). Computer programmes have been elaborated for understanding simple texts dealing with such events (SAM, FRUMP, POLITICS). A script may be concerned with a possible occurrence of events, but also with the order of their occurrence. Furthermore, the existence is assumed of metascripts – abstractly formulated scripts with a minimum of specifications and structures of knowledge that marshall various "scenes" into a coherent sequence of behaviour. This is a handy tool in experimental psychology for investigating cognitive schemas (use is here made e.g. of method of omitting important events from the sequence). Social psychology, in turn, makes use of the environment context evoking a certain behavioural script in studying social behaviour.

3. COGNITIVE PSYCHOLOGY AND QUESTIONS OF MENTAL REPRESENTATION

Cognitive psychology is a certain methodological approach rather than an exactly defined area of investigation or a new discipline. A Marxist and an idealist (mentalism and phenomenologism) orientation have come to be evolved in it. It concentrates on complex cognitive systems or structures. According to Estes [18] it investigates every aspect of information processing. acquisition of concepts about the world and their utilization in decision-making and carrying out of activity.

A wholist and structural-informational approach to knowledge (an antithesis to traditional functional psychology) stands in the foreground; as a result of a mutual activity and conditioning of cognitive processes, the sharp separation between perception and thinking is toned down; is not altogether abliterated, the generalizing memory function ensuring its transition to thinking. The various processes are understood as successive stages in the solution of the relevant task. The regulatory elements are elucidated here within the framework of a single functional structure. According to Rogovin [19. p. 125] "cognitive psychology is a considerable step forward in comparison with the preceding periods of general psychology".

Klix [20] sees in cognitive psychology an integrating value that derives from its orientation to invariant attributes of those psychological proccesses which are based on information reception, processing and utilization. He advocates the

need of unifying two great areas of research – cognitive and motivational psychology. As a matter of fact, semantic structures represent an individual reflection of reality and also characterize their bearer's personality.

From more recent attempts at a synthetic presentation of the problems relating to cognitive psychology, mention might be made of those by Wickelgren [21] whose theoretical conception is derived from a combination of the associative, structural-linguistic and informational approach.

According to Simon [22], the conception of information processing has totally altered the face of cognitive psychology. Nevertheless, the models originally formed for various components (perception, memory, problem solving) should be integrated according to common architectonic principles and thus be made to contribute to the general theory explaining human knowledge in all its manifestations.

At least some of the new approaches to an investigation of thinking might be noted briefly. Rasmussen [23] in his scheme of data processing by man laid stress on a cooperation between a high-capacity system of parallel processing functioning unconsciously and a sequential conscious processing with a limited capacity. The unconscious processor comprises an inner dynamic model of the world and deals with routine tasks (complex and exact sequences of activity are recalled with the aid of individual cues and are speedily realized as a result of a simple feedback control). The high capacity of unconscious sensorimotor functions protects the low-capacity conscious cognitive functions from overload in routine tasks.

Linhart [24] deals with questions of thinking within the frame of reference of control of human activity (structural-functional conception). According to him, thinking takes place as a cognitive self-organization on the basis of a subject-object relationship. The highest type of self-regulation is that taking place on the plane of mental abstraction (man graphs the principles involved in the task solution and directs his activity accordingly).

It may be inferred that cognitive psychology does not represent a unified school of thought (nor has it its explicit founder; theories and researches have subsequently been subsumed under this designation of authors who had laid stress on cognitive processes, their interfunctional bonds, regulatory task, similarity with steps in computer information processing, etc.). Cognitive psychology with a Marxist orientation, however, has contributed considerably both to the theory of cognition (it justifies Lenin's theory of reflection) and also to social practice (cognitive aspects of work activity).

Within the scope of cognitive psychology, considerable attention is being devoted to mental representation. The starting point of the thinking process being also the precondition of psychic control of behaviour, is an inner model, a mental representation. A detailed analysis of the approaches in this domain may be found in our studies [25], [26].

Our premise in an attempt at defining metal representation lies in a system approach, an interfunctional apprehension of psychic phenomena, and a psychic-regulatory

conception. Studies up to now go to show that it is intersection of several psychic processes (isolatedly understood in functional psychology, particulary those of perception, imagery, memory, thinking) that are formed in virtue of the principle of reflection as a result of man's activity (practical and mental) and of regulating this activity. It may originate on various hierarchical levels of the psychic and hence, may have a varying level of abstractness. This system approach my be expressed in different languages (e.g. symbolic, iconic, mixed). The structure and language of representation affect its effectiveness in the control of activity (e.g. problem solving, planning). No attention has so far been devoted to an incorporation of mental representation in to the overall personality structure.

We have investigated the process of creating and transforming mental representation under simulated laboratory conditions with operators and undergraduates, making use of a matrix of 3 × 6 blank circles, in which we set up various combinanations of 5 black circles. Subjects were asked to remember the schema and to transform it mentally (to shift it, to turn it laterally and vertically, etc.). In addition, they had to estimate the similarity of the schemas and underwent several psychodiagnostic measurements.

The result pointed to a different degree of difficulty of various types of mental operations (e.g. the most difficult proved to be a mirror turning about the vertical axis), to the role of memory and intelligence, to the types of information coding, etc. For more detailed data, see [27].

4. PROBLEMS AND PROSPECTS OF COOPERATION

The interface between psychology and the theory of artificial intelligence has come to be the scene of a development of the theory of modelling cognitive activity. Computational modelling serves psychology as a research technique and help to set up hypotheses on the essence of human intelligence [28].

To improve cooperation, it is essential to clarify the terminology (artificial intelligence and psychology often make use of terms with a different real connotation) and to assess whether cybernetic terms permit to express the specificity of psychological phenomena. Thus, for instance, information theory makes no account to the "value" of information to man. GPS simulates only certain aspects of thinking in solving closed problem (it leaves out all emotional-motivational processes). Human heuristics is characterized by the formation of concrete goals, by a dynamic transformation of means to an end. Consequently, human thinking may not be reduced to information processes and a heuristic programme does not as yet constitute a theory of thinking.

A need of investigating man's psyche is especially under scored by Soviet cybernetic scholars when pointing out the urgency to go beyond the framework of a narrow technical interpretation of artificial intelligence. Its improvement will be promoted

by an introduction of inner essential traits of the human intellect (needs, an emotional control of search, setting up of goals, selective image of the situation) into computer work [29]. If automata are to model the laws of human psyche, their inner structure must permit models of objects to be created and manipulated.

On the other hand, an elaboration of a general theory of thinking should exploit concepts of the systems theory and of cybernetics (hierarchical organization of elements, mental regulatory mechanisms). A promising feature in connection with an inner representation appears to be a utilization of the frames theory, the fuzzy sets, as well as of the IA concepts on representation.

In general, cooperation between psychology and artificial intelligence might contribute to detection of specific mechanisms of cognition (and particulary thinking activity) and to promote further development of the theory of artificial intelligence and its practical application.

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