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This article presents a critical discussion of the use of the notion "frame", especially by computer scientists, as a theoretical construct to describe the cognitive representation of information. It is argued that an adequate description of "knowledge" requires the utilization of the notion "schema" as the theoretical construct. Based on this discussion, the construction of abstract cognitive models is proposed. Further, the concept of a memory is considered superfluous because the assumed cognitive structure is conceived as being essentially "shapeless" and not directly accessible through consciousness. The basic assumptions of models too concrete in nature are examined and it is argued that the object orientation and a reduction of "knowing" to some effective procedure governing theoretical discussions within the field of Artificial Intelligence and recently in Cognitive Science is seriously misleading with respect to cognitive functions and the development of knowledge.

Keywords: Cognitive models, constructive routines, data abstraction, frame, memory, schema.

CONTENTS

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B.B.

1. INTRODUCTION

Computer scientists have recently had some impact on the field of cognitive psychology. Especially within the field of Artificial Intelligence (AI) researchers have developed models of human problem solving (Newell & Simon, 1972) assuming it impossible for anyone (except for a supernatural being) to gain complete knowledge about the world.

Despite the fact that ordinary everyday perception of objects (persons, concrete things) can be made with absolute certainty, this phenomenon is described as "expectation" or "hypothesis". Further, the models developed assume that human cognition is expressible in the form of a computer program. It is hypothesized that human beings function on the basis of some formal logic in a one-to-one correspondence with the computer program. Thus, it is implied that human beings have complete knowledge of the adequate response. Contrary to this very simplistic expectation, few would deny that "knowing" cannot easily be reduced to some effective procedure, where the outcome of necessity is known a priori. Indeed, conscious decision-making and the judgment of a behavioral outcome is something that cannot be covered by the doctrine followed within the field of AI.

Now, with the beginning of an understanding of how to build a machine that in an algorithmic way can perform something that has been labelled "knowing", it becomes mandatory to ask questions about how cognitive functions are conceived in the formal as well as in the factual sciences. What becomes important is to analyze the logician´s viewpoint as expressed in philosophy and to compare this with the assumptions underlying the models of knowledge representation proposed

in the natural and social sciences.

Computer scientists seem to believe that they can represent "knowledge" (Bobrow & Winograd, 1977) and make a Turing machine which "understands" natural language (Winograd, 1972). Therefore it becomes necessary to analyze how the models explain the individual´s ability to differentiate itself from the environment.

A well-known fact is that the machine behavior of necessity is rigidly insensitive to context. A question of particular import therefore arises: How can the proposed models cope with novelty?

Although it is not of major concern how the proposed models extend in the theoretical explanations of neurological processes, this aspect should not be ignored. Finally, objects and events are of different kind which means that any proposed model must account for these differences.

2. THE FRAME HYPOTHESIS

Scientists working within AI have recently proposed the terms "frame" (Minsky, 1975) and "script" (Schank & Abelson, 1977) in an effort to define a unit, which can be used as a building block in a computerized representation of knowledge and the processing of natural language. These terms, as will be shown here, can easily be subsumed under the frame hypothesis.

2.1 Philosophical Roots

The important role of internal processes in perception and thought is a central theme in philosophical writings. In particular the frame hypothesis seems to be anchored in Leibniz´ monad system. Leibniz

conceived the world as composed of simple nonsensory or immaterial Gestalts. Each Gestalt comprizes a microworld in itself. That is, each Gestalt contains a synthetic representation of a two-dimensional whole, i.e. a spatiotemporal representation of a certain environment. The world is conceived as a set of Gestalts and thought of as being built up by the relations which these static units have to each other. These relations consist of the order of the Gestalts.

Thus the frame (or Gestalt) approach illustrates a contextual framework in which the definition of unanalyzed wholes, Gestalts, symbols, units or primitives takes place through their respective positions within a unity. The unity can be defined as a standard context. In addition the frame approach makes no provision for local dependency, interaction or non-stationary processes.

The frame hypothesis implies a static two-dimensional stimulus pattern. Therefore, it is hard to conceive how motion and other events can be satisfactorily included. It is also difficult to give a conclusive explanation of how a series of Gestalts can be integrated; some sort of higher order cognitive activity has to be assumed.

2.2 Psychobiological Perspectives

Within the field of the neurosciences, Szentagothai and Arbib (1974) proposed the term "slide" as a nonsensory unit of perceptual organization. They put forward the hypothesis that the visual system detects and utilizes features on the basis of which a "slide" generator inserts certain slides in the foveal.

Slides are "designed" with the aim of supplying the perceptual system with context. In this model a "slide-box" is to be thought of as containing an overall pattern of nonsensory figures. Every slide

is equipped with an input side appropriate for matching with sensory input features. The proposed output side is configured in such a way that appropriate signals can be sent to the central processor unit for resolving redundancy and to a unit which distributes motor control. Alternative ways of solving a perceptual task on the basis of the slide-box model look like the well-known attempts to develop programmed learning material based on S-R theoretical principles. This material was designed both with unitary paths and multiple branching, but without any device for bringing unity out of the primitives within a certain context. In the natural environment there hardly exists anything like the perception of static stimulus patterns, and many environments do not provide enough information to be processed, regardless of the fact that Helmholtz´s famous equation (size of object equals the distance of the object multiplied by a constant) can be used to calculate and explain why the environment is perceived correctly with respect to "perceptual constancies". On the other hand it is a well-known fact that the phenomenal environment does not reflect the physical environment exactly. The decisive argument is that no point-to-point relation exsists between physical objects and the perceptual product of a "slide" ("the perceptual conclusion"). From a logical point of view Johansson (1974, p. 132) treats the case of nonmotion as a perceptual null hypothesis, that is, "the perception of a stationary environment by the stationary eye" (fixated optokinetic nystagmus).

A method for the investigation of internal forms of visual activity has been proposed by Gippenreiter and Romanov (1974). These authors (1974, p. 245) show "lawful changes" in the characteristics of this mechanism. Increasing visual attention suppresses it, whereas a

decreasing visual attention disturbs it. The result may be interpreted in terms of a microstructure and an activity existing within a macro-structure (i.e. contextual structure).

Thus the frame hypothesis assumes that "features" are utilized by feature detection systems and that the end-product of perception is the outcome of associative processes, in which a two-dimensional stimulus pattern becomes enriched somehow by the activity of some higher order cognitive functions (i.e. the creation of a third dimension or of depth).

2.3 Cognitive Science Perspectives

The trends which can be discovered in the literature on AI have recently led to the proposal of a new label, "Cognitive Science", with the aim of covering a development away from thinking in terms of classes based on binary logics, and towards thinking in terms of functions. But this change needs to be discussed, and if it is realized, it would be helpful to make explicit the way it has manifested itself in the formulation of new cognitive models.

In connection with research on "knowledge representation" at the Massachusetts Institute of Technology (MIT) Minsky (1975) suggested the term "frame" to designate

"... a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child´s birthday party".

Thus, a frame can be conceived of as a description of a familiar scene, in which the scene director arrange the requisites (i.e. objects). To scenes belong not only things but also atmosphere, which

can be created by rules for the composition of the objects (things, actors). Within a scene, actors play certain roles according to a set of rules. These have to be internally consistent. The rules precisely specify for the actor how to behave from one moment to the next.

Minsky´s approach in fact converges to an understanding that the development of cognition is a matter of determining the processing of data input. Thus cognition is nothing more than a determined calculation, e.g. a formal logical process which has only one outcome. Minsky´s frame approach seems to be a purely instrumental one, which is defined in terms of operations of positions suitable for a frame generator or a Turing machine. However, such positional definitions are only possible if one can define a restricted pattern for the distribution of elements (in an, at most, two-dimensional area) of the kind that are contained in a "living room" or make up a birthday party. The proposed approach on the other hand makes no provision for such cognitive activities as planning ahead, resolving inference problems or judging behavioral outcome. Further, under the frame hypothesis it is assumed that relatively independent paths exist, which can be stored in form of a program at some location in the computer or human memory. As a consequence, an activation of the system initiates a search for and a retrieval of a suitable path and its connected frames. It is, then, believed that recognition has been produced. If appropriate paths can be activated it is assumed that the system exhibits "learning" or "inference making" abilities. Natural language understanding, therefore, is the result of feature detection and signalling of the type of stored information that has to be drawn from the computer´s memory device.

However, characteristic of understanding and comprehending in-

formation is the articulation of novelty. Contrary to this, a frame is modelled on old information, which means that the model of frame can only handle already articulated information and therefore only detect "sameness" and establish "boundary conditions". The hypothesis of a frame does not allow for a test of uniqueness, which means that this approach is unable to take into account atypical acts, e.g. acts for which no rules are prescribed. When a frame is employed one automatically knows what to look for and where to look for it.

Atypical acts, however, are a prerequisite for an articulation of the nature of new information. Minsky (1975) therefore proposes that several kinds of information might be attached to the "frame", such as predictions of future events, and instructions for appropriate reactions, if the "expectations" are not realized. Clearly, this advice does not circumvent the problem that Minsky proposes a model of a rigidly organized manifest data structure. Further, the frame system must be provided with a steering and control mechanism that guarantees that only such frames from a set of frames can be retrieved which have been successfully matched to the input features that occurred.

Schank and Abelson (1977), on the other hand, suggest that a "script" may contain cues to alternative paths, including deviant paths by means of which specifications are given in cases where a "standard script" does not apply. This is in good agreement with Minsky´s viewpoint. Originally, "scripts" were proposed by Abelson (1973) and described as conceptual structures which explain to an individual why a specific social action or sequence of actions has occurred or might occur. Schank and Abelson (1977), however, conceive a script as description of a prototypical sequence of events, such as

those involved in eating at a restaurant. A script is now equated with a "standard situation". Consequently, Schank and Abelson (1977, p. 41) define a script as

"... a predetermined stereotyped sequence of actions that define a well-known situation".

This conceptual redirection with respect to the meaning of a script is intended to imply a change from latent structures to manifest ones. Thus, both Minsky (1975) as well as Schank and Abelson (1977) propose the frame hypothesis with the aim of supplying the computer with "context" much in the same way as Arbib does for his visual system. On the basis of frames these authors suggest, in essence, that information processing should be seen as preprogrammed relations among successive ordered Gestalts.

In Schank and Abelson´s "restaurant script" there have to be certain figures as waiter and guests. In this respect any script or set of scripts has its lexicon and set of rules which define it as a recognizable stereotype. Events happening within a script have by definition a uniform or familiar character and thus constitute merely a static state. Attention is kept at a minimum as long as it pertains to ordinary events, transitions or actions within a script, e.g. the restaurant script.

Contrary to the frame theorists´ intention, the script as a "unit for representation of knowledge" seems to function much like an idiomatic expression which can only be understood in one way. Thus, recognizable stereotypes of this kind are analytically derived, concrete and appropriate for operations such as addition, substitution and deletion. They function on the principle of minimum attention in

the selection of pieces of data, and they may also have some useful functions in a decision-making process. However, "judgment" remains outside the frame approach.

The frame approach emphasizes syntactic rule structures together with selection restrictions which can be called effective procedures of algorithms, modelled on classical logical and mathematical principles, such as local independence, linear relations and stationaries. These have been basic in scientific analysis. Thus, Schank and Abelson´s latest understanding of a script seem to be very much like Weizenbaum´s view. Weizenbaum (1976, p. 3) states the following:
"The script is a set of rules like those that might be given to an actor who is to use them to improvise around a certain theme."

From the point of view of frame theorists, understanding seems to be equated with retrieval, selection and grouping of stored units. Anything novel with respect to input has to be conceived as a failure in the matching process. With the perspective held within AI, past experience can only provide a repertoire of stored information. The structure of information is fixed within the frame employed and cannot be novelly recombined. Such a possibility would destroy the captured event and thus the data structure. In the case of destruction, context would have to be conceived as noise distributed over the set of data.

To sum up, from the psychological point of view, frames would be a very undesirable mechanism preventing the individual from making inferences and judgments necessary for an orientation toward increased refinements and change of what previously was understood as being of significance in a variation rich environment. Well-formed scripts in the mind (or brain) of a human being would be precisely what disable

anyone to act properly in connection with upcoming events of novel significance.

Finally, it should be pointed out here that the Turing machine by many scientists is conceived as a highly perfected model of the brain and a representation of what a nervous system could imply (because of its formal logic foundation). Nevertheless, the psychologic has to be modelled and explained. By this is meant that the causal chain of events in the machine has to be circular and augmented with extra-sensory connections between the two ends. Otherwise, it is impossible to translate it into implications of significance for survival in an ever changing environment.

Bregman (1977, p. 254) in an article on "Perception and Behavior as Compositions of Ideals", claims that notions like "ideas", "ideals", "concepts", "paradigms", "frames", "rules", "regularities", "components of deep structure" of "schemata" refer to the same phenomenon. This is an unfortunate confusion of terms that denote quite different things. For example, Kant's conception of an idea is that it only functions as a heuristic concept (cf. H. Cassirer, 1970, p. 44). A schema, on the other hand, is by Kant conceived as a device needed to combine sensuous data and categories. "Schema", furthermore, has become a term of major import in various approaches to the development of a theory of knowing. Therefore, this term will in the following section be analyzed and discussed in considerable detail.

3. THE SCHEMA HYPOTHESIS

The hypothesis of a schema as the basic device for the creation of cognitive organization assumes primary activity and cyclic processes

in the development of knowledge. The concept "schema" is synthetically derived and appropriate for non-linear operations.

The hypothesis of a schema as primary means in the development of knowledge was first utilized by Kant in the 18th century to label some cognitive mechanism which he postulated necessary as mediator between such cognitive functions as categories on the one hand and sensory input on the other, or, in other words, to label the product of imagination ("Einbildungskraft"). Further, the notion of schema was used as device for establishing relations between events, stretching over series of instances ("Segments einer Zeitreihe"). Thus, to enhance the understanding of the concept schema it seems to be necessary to outline its philosophical roots in some detail.

3.1 Philosophical Roots

For Kant, the experience of objects and events is not mediate but immediate. For him, there is no doubt that a thing exists in itself. Despite of this assertion, Kant tries to make the case that human beings cannot possibly know a thing by the senses as it is in itself. What humans can experience are the properties of a thing. This means that its appearance is "intuited" by the senses of the organism. Kant (in Ellington´s translation from 1977, p. 50) writes:

"Hence appearances must be subsumed under the concept of substance, which as a concept of the thing itself is the foundation of all determination of existence, or, secondly - so far as a succession is found among appearances, that is, an event - under the concept of an effect with reference to cause, or, lastly, so far as coexistence - under the concept of community (action and reaction). Thus a priori

principles form the basis of objectively valid, though empirical, judgments - that is, of the possibility of experience so far as it must connect objects as existing in nature. These principles are properly the laws of nature, which maybe called dynamical."

Kant´s argumentation, cast in modern thought, seems to imply that "information" is carried by physical entities, such as books, sound waves, chemical substances or neural networks, but it is not in itself material. Then for the brain to build a cognitive code, the existence of a phenomenon as a priori principles may be possible. The phenomenon referred to here is "the sensuous representation of things, to which space and time especially belong".

Thus, the assumption is that the brain builds up a device underlying symbolic representations of causal and other relationships of the environment. This device is called a schema and conceived as the basic tool for intellectual functioning of a human being. Kant (in the translation of Smith, 1979, p. 335) writes:

"Now it is clear that there must be a third thing, which is homogeneous on the one hand with the category and on the other with the appearance, and which thus makes the application of the one to the other possible."

What Kant wishes to express is that one could make no sense of isolated observations without taking into account the cognitive model (or tool) in terms of which humans organize their perception of the surrounding environment and indeed how language map into those structures.

For Kant (see H. Cassirer, 1970, p. 28)

"... it would be absurd to say of a category that it could be intuited through sensation...",

and consequently, he needed some mechanism which could subsume appearances under categories. Kant´s solution of the problem stated is given in the chapter on the "Schematism of the pure Concepts of Understanding" ("Von dem Schematismus der reinen Verstandesbegriffe"). Here (see E. Cassirer, 1922) it is stated that predicates or determinants need not only apply to material things. As Kant points out, all appearances have to conform to time because the perception of an object takes place in time. Further, categories are mere logical functions. However they receive their meaning from their applicability over time, i.e. they transcend themselves.

Thus a schema is, according to Kant´s definition, nothing but a transcendental determination of time. (It maybe appropriate here to point out that Kant is not concerned with the explanation of the origin of experience but with what lies in experience.)

According to Kant, the schema is the product of the "ability of imagination". Thereby he refers to a synthesis of a manifold of observations or experiences which becomes aggregated and unified over time. Also, he clearly points out that "imagination" in no way has anything to do with a "picture" or an "image". This means that one has to keep separate the schema from the picture, image, slide, frame or script.

The functional use of schemata in the development of concepts ("Verstandesbegriffe") is by Kant called "schematism". This is the mechanism which makes possible to build up a concept out of a manifold of possible appearances. But no empirical concept can be developed in the absence of homogeneity (cf. H. Cassirer, 1970, p. 48). Without the presupposition of homogeneity no experience would be possible

either (cf. Gibson, 1979, p. 17). Further, it is the very relativity in the choice of a space-time reference system that makes it impossible to attribute, according to Kant, a priori validity to objects (cf. H. Cassirer, 1970, p. 5).

Finally, Kant comes to the conclusion that categories without underlying schemata can only be understood as cognitive functions of categories but cannot represent reality. Categories get their content from the concrete experience intuited through sensory systems. This is accomplished by the intellectual mechanism, called schematism. But at the same time, the comprehension of the "intuitions" becomes constrained by the sensory input. This is why the brain has to function on incomplete sets of data.

Thus empirical validity can be achieved by the experience of "things" and the provision of a schematism by which the organism can modify in a cyclic way the reception of information and update the internal models of itself and the environment. The unity of a concept is achieved by this synthesizing process in which variety becomes specified. This is what Kant calls "lex continui in natura" (see H. Cassirer, 1970, p. 48).

From the philosophical point of view, Craik (1943) reconsidered the notion schema with special emphasis on symbolic processes. Craik put forward the hypothesis that humans discover the world by means of symbols. Therefore, Craik considers the schema as the necessary device for the formulation of hypotheses and their testing against empirical data. (Note: For Kant it would be a mistake to equate a symbol with a schema.)

Craik conceives symbols as abstract codes whose definitions are

wholly arbitrary and therefore can only be understood by those who have the same common outlook. Craik (1943, p. 29) writes:
"... the fundamental power of words or other symbols to represent events ... permits us to put forward hypotheses and test their truth by reference to experience".

In essence then, the schema is considered as having symbolic properties. This means that it signifies something but is distinguished by the individual himself from its significate. Thus when a person describes an event verbally, he distinguishes his description from what he is describing. According to Craik, symbolic descriptions of sequences of events may be regarded as embodied in nets of verbal expressions.

3.2 Psychobiological Perspectives

In the early years of this century, Head (1920) found the notion schema suitable as a label for designating a dynamic structure which conserves the relation between continuously changing postures and which integrates fresh arriving sensory input in the brain (cortex). It is clear from the writings of Head that he understands the schema as an extremely flexible and dynamically structured cognitive device with the power to modify the continuously ongoing reception of sensory input. Head (1920, p. 831) argued:
"There are no basic physiological activities corresponding to 'primary sensation'. /.../ Qualities such as pain, heat and cold are abstracted from the psychical response and spoken of as 'primary sensations', but they have no exact physiological equivalent in the vital reactions of the peripheral mechanism."

Both Kant as well as Head conceive the schema as an immaterial but dynamic structure which organizes experiences and the behavior of an organism.

In the days of Head, the brain was considered an inflexible structure. It was generally believed that the number of cells and the way in which those cells are organized is rigidly determined from birth. Despite this conception of the brain, Head (1920, pp. 605-606) states the following:

"Every new posture of movement is recorded on this plastic schema, and the activity of the cortex brings every fresh group of sensations evoked by altered posture into relation with it."

Head's position has been confirmed by the literature on brain research (cf. e.g. Oatley, 1978; Young, 1978) which reports experiments conducted with monkeys and rats, revealing that the brain develops highly plastic organisations of cell nerves. The reported phenomenon of "transposition", for example, indicates that the organism may respond not to the particular stimulation (as von Frey in 1895 believed, see Uttal, 1973) but to relational properties. Head showed that these can be destroyed by brain lesions inflicted, e.g. by a stroke. In this connection, Head (1920, p. 606) reports the following observation:

"One of our patients had lost his left leg some time before the appearance of the cerebral lesion which destroyed the power of recognizing posture. After the amputation, as in so many similar cases, he experienced movements in a phantom foot and leg. But these ceased immediately on the occurrance of the cerebral lesion; the stroke which abolished all recognition of posture destroyed at the same time

the phantom limb."

The essential point in this observation is that a schema hypothesis of cognitive organizations in the brain seems to be required, otherwise efficient transacting with the environment is difficult to account for. As support for this statement one can claim results from studies of neural coding of sensory quality. Melzack and Wall (1962), for example, concluded that beyond the receptor levels, spatiotemporal pattern representation should be accepted as predominate.

Head´s concept of a schema implies the notion of primary cyclic activity. Thus, the schema incorporates the notion of feedback. Without this it would not be possible to think constructively about a theory of knowing. To account for the phenomenon of cognitive organization, Helmholtz put forward his famous hypothesis of "unconsciousness inference". Further, it would not be possible to account for the phenomenon of conditioned reflex, studied in the S-R tradition, if one abandoned the notion of reconfirmation. If so, the phenomenon of conditioning would disappear.

The same basic outlook, namely that stimuli do not impinge upon a neutral organism, is taken by von Holst and Mittelstaedt (1950). They propose that stimuli are processed by a comparator against anticipated input. However, Szentagothai and Arbib (1974, p. 338) note that "... one cannot expect such reafferenz to yield more than approximate compensation".

But these authors do not deny the significance of the concept of corollary discharge. Gippenreiter and Romanov report (1974, p. 238) in their experiments on the internal form of visual activity that the involuntary fixation mechanism manifests itself in different

conditions and that a stationary point elicits static fixation. Moving stripes, on the other hand, evoked dynamic fixation or tracking.

The brain can be considered as an enchanted loom (see Young, 1978; Piaget, 1978) constantly weaving changing its connections and rearranging its circuits. Young (1978, p. 12) considers the brain as a physiological system that

"... inherits the capacity to build ... a model indicating the actions (of the organism) that are likely to be successful in the enviornment that its ancestors and itself have met".

Young basically thinks of random possibilities for the cells in the brain to form certain connections. Those that are activated by the environment become linked, whereas other randomly formed connections burn out, e.g. become disconnected. From his point of view, no inherent necessity exists for the brain to abstract a certain variety of structural features and to continue any particular structure. The underlying conception of Young´s position is that the brain does not function on immediate sensory input but on abstracted and coded information.

For Head (1920, p. 605), changes in the "propathic conditions" (i.e. to feel or to be affected of gross pressure, pain, heat or cold) rises into consciousness as an apprehended postural change. For a recognizable "before" and "after" condition in changes of posture, Head proposed the term "schema". He writes:

"By means of perceptual alterations in position we are always building up a postural model of ourselves which constantly changes."

Implicit in this viewpoint is that perception means analyzing a scene to the extent that a model of it can be synthesized. Thus the

primary purpose of recognizing objects is to interact with them (including oneself). Head assumes that every transition from one postural state into another will have as its effect an enrichment of the schema.

It follows that only on the assumption of schemata it is possible to imagine that an organism is capable of testing hypotheses.

Grossberg (1980, p. 6) tries to answer the question about the brain mechanism that can build a cognitive code, despite the inability of an individual nerve cell to discriminate between behavioral meaningful information and coding errors. He tries to do so by means of a number of thought experiments. On the basis of these, Grossberg gives the following answer:

"... feedback is necessary to stabilize the development of behaviorally meaningful codes in a rich input environment. The feedback process includes attentional mechanisms, and the stabilization of developing codes leads to gating phenomena, or the emergence of critical periods, that are dynamically maintained by feedback processes".

Fundamental for the reasoning of psychobiologists seems to be the possibility of a coding mechanism which can build a schema by altering the probabilities of the effects of feature detectors. Basically, this assumption is modelled on the flip-flop mechanism of a Turing machine. Physiologically, this seems to be done by an inhibitory mechanism. Through inhibition the effectiveness of interactions of the cells are either enhanced or blocked. Grossberg postulates an "on-center off-surrounding" cellular system.

Thus, after integration into an ensemble of neurons, each feature detector becomes a unit which can produce only one action, whereas

initially it could have been part in two or more actions. The function of the established unit is to "remember" which paths a sensory input previously had activated. (For a more detailed description of the flip-flop conception, see Weizenbaum, 1976; Young, 1978.)

3.3 Cognitive Science Perspectives

Only a decade after Head (1920, p. 606) stated that it is the existence of schemata that give humans "the power of projecting the recognition of posture, movement and locality beyond the limits of the body" Bartlett (1932) used the concept in his studies of "remembering". To him, the integration of the idea of self-representation, is the major extension of the concept beyond what Head had covered. Though, this aspect is already present in the writings of Head.

According to Bartlett, the schema seems to be the necessary device for an organism to distinguish itself from the environment, i.e. to come to self-understanding. In this perspective, the schema is the mediator between meaning and being. Further, Bartlett emphasizes, virtually in agreement with Kant and Head, the reconstructive capabilities of the schema. He states that memory is more likely to reconstruct the past than solely retrieving it. Thus Bartlett (1932, p. 201) uses the term schema to label

"... an active organisation of past reactions, or of past experiences...".

Through the device of a schema, the organism constructs, according to Bartlett (1932, p. 202), a model of the environment, despite the fact that incomplete data sets might be available. He writes:

"If only the organism could hit upon a way of turning round upon its

own 'schemata' and making them the objects of its reaction, something of the sort might perhaps become possible. An organism which had discovered how to do this might be able, not exactly to analyse the setting, for the individual details that have built them up have disappeared, but somehow to construct or infer from what is present the probable constituents and their order which went to build them up."

In his experiments, Bartlett tried to prove what the quotation given states. He assumes that the process of synthesizing requires extensive use of schemata, otherwise details cannot be of much use in the abstraction of information. Further, for Bartlett, it seemed impossible to have a theory of memory based on storage and retrieval of isolated elements. Thus, it was obvious for him that the perceptual system of an organism cannot be tied to immediate sensory stimulation. The association of stimulus cues seems to be only one stage of establishing a course of action which has been artificially singled out for experimental purpose. It is a well established fact in perceptual psychology that spatial properties of various regions of the retinal image are not well reflected in experience.

Bartlett views schemata as tools of memory which enable the organism to differentiate between an existent or desired state of the environment on the one hand and an existent or desired state of the organism itself on the other. Thus the schema is the fundamental instrument for the discovery of the external world and, eventually, the forming of the concept of "self".

From a developmental point of view, it is mainly Piaget (1971)

who extensively employs the notion schema. He has tried to integrate in his psychogenetic growth theory the perspectives of Kant and Craik as well as Head and Bartlett. What is original and a further extension of the idea of schema refers merely to the fact that he considers the schema existing not only in cognition but also in behavior, i.e. before any thought or any idea of self has been established. The schema is, according to Piaget, the basic control mechanism in the development of the organism´s behavioral and cognitive capabilities.

The schema is conceived of as being conserved in the behavior of the organism itself. The preservation of a schema is, as Piaget (1971, p. 187) points out, not properly conceived as a problem of memory, because the schema of an action is "the quality in the action". Thus a schema is not a unit of memory, which can be found by an extensive search in the cellular system of the brain.

The basic mechanism assumed by the theory of psychogenetic growth is "progressive equilibration" or "autoregulation". Through the functions of assimilation and adaptation, the schema can become enriched, differentiated and partly restructured, although a re-structuring of a schema in its totality would destroy it. Piaget (1971, p. 7) assumes in the earliest stage of development simple, unitary schemata, as a result of the "direct coordination of actions without any representation of thought".

This assumption would imply, as Kant suggested, some preexisting general structural principle that generate behavior. Based on the same basic outlook, Bregman (1977, p. 271) states:

"... the character is 'in' the behavior. It is also in exactly the same way 'in' our perception".

Piaget assumes that the organism develops schemata on the basis of a space-time coordinate that orders regularities. This is in agreement with Kant´s assumption that e.g. "quantum", "momentum" and relations such as "interdependency" or "causality" are basic categories and fundamental for the development of knowledge. Piaget, too, describes investigations into such concepts as "number", "space" and "logic" as fundamental for the child´s development of knowledge. Piaget (1971, p. 84) writes:

"... the development of intelligence involves certain aspects of progressive organization...".

"This organization consists of a construction of operational structures, beginning with the general coordination of action. This construction is brought about by means of a series of abstractions (or differentiations) and of reorganizations (or integrations)."

Thus schemata become generalized through the process of auto-regulation. By means of assimilation properties of significant events are sorted out so as to fit the demands of the structure that already exsists. If the properties of an occuring event are not completely assimilated, then Piaget speaks of an "aliment" for the schema. An aliment represents a challenge for the individual and give rise to an articulation of novelty. Thus the development of a schema is successively regulated which means that the individual gradually become "equilibrated" to cope with events of growing complexity.

In essence, then, any meaningful analysis of cognitive development and behavior should be based on the conjunction of events and an analysis of how the conjunctions restrict possible events which might follow. From this point of view interaction of an organism

with its environment requires a tool for an abstract representation of what happened before and what follows after the appearance of an event. The importance of this consideration is clearly expressed by Russell (1948, p. 287) who writes:

"It is clear that time is concerned with the relation of earlier and later, it is generally held also that nothing of which we have experience has a merely instantaneous existence. Whatever is earlier or later than something else I shall call an 'event'. We shall want our definition of 'instant' to be such that an event can be said to exist 'at' certain instants and not at certain others. Since we have agreed that events, so far as known to us, are not merely instantaneous, we shall wish to define 'instant' in such a way that every event exists at a continuous stretch of the series of instants. That instants must form a series defined by means of the relations of earlier and later is one of the requisites that our definition must fulfil."

Russell´s definition implies that events must possess a certain structure and that this must show certain familiar properties, otherwise one could not perceive it. Thus an event is characterized by certain sets of familiar and unfamiliar properties, independent of its material or immaterial manifestation.

A structure characterizing an event is assumed to contain certain unifying elements and connections. Therefore, one cannot single out these and define them independently of the connections involved. This structural view was recently expressed by J.J. Gibson (1966, 1979) and put forward within the framework of an ecological approach to perception. Gibson claims that the perceptual experience is direct and flows immediately from a schema (superordinate components) under-

lying a particular pattern of retinal stimulation. This statement is based on the assumption that the perception of objects is not based on the perception of shape but on the perception of "shapeless invariants over time". According to Gibson, the brain seems to differentiate perception and behavior on the basis of invariants or groups of invariants which make possible an internal representation of the behaving organism itself, the environment and the relationships between organism and environment such as they exist at a certain place and point in time.

Gibson (1966, 1979) claims that the notion of labelled lines or point-to-point correspondence between sensory input and representation in the cortex does not hold. For him perception is not based on sensation but on information pick up (see Gibson, 1979, p. 56). This can be supported by Szentagothai and Arbib´s (1974, p. 332) observation, namely:

"There seems to be one common principle that underlies the mapping process: groups of primary afferents are arranged within each dermatone in such a manner that peripheral receptive fields of each group of afferents form characteristic sequences on the body."

This essentially topological mapping of sensory input has as its consequence that the same body region may project to different places in the cortex. This may happen each time when a projection occurs within a different local context and with different neighborhood relations. Thus, further analysis must, as Szentagothai and Arbib (1974, p. 332) point out, involve "Loss of information about actual localization of input but must extract coincidence or conjunction between different stimuli as we go from sensory representation to a

motor representation". Gibson agrees that stimulation is necessary for the activation of the perceptual system. But the stimulation of the receptors in the retina, he points out, cannot be seen. Instead, the function of the retina should be thought of as means of registering invariants of structure (Gibson, 1979, p. 56). This hypothesis, is intended to close the gap between "perception and knowledge" (see Gibson, 1979, p. 258).

Both Piaget and Gibson agree in their formulations when they state that theoretically there is no place for a concept of memory, but on the other hand both do not deny that past experience is of import for the development of formless invariants. And this is also what Kant was arguing for when he proposed his invariants over time in the form of transcendental schemata".

4. INTEGRATION AND CONCLUSION

As Piaget (1971, p. 2) observed:

"... most biologists agree that knowledge consists basically of information drawn from our environment".

The disagreement centers merely around two different theories of the information processing mechanism in the brain. The theory based on the frame hypothesis emphasizes one-to-one correspondence between a single stimulus gradient and a resulting pattern of nerve connections. The theory makes reference to the absolute position of the part of the body to be effected and to certain locations in the cortex from where appropriate information can be retrieved. Some calculation, which is not consciously noted, may also occur. Cognitive psychology sometimes refer to the unexplained term "cognitive calculation", which may be

a result of Helmholtz´s famous doctrine of "unconsciousness inference". The theory also assumes some feature detectors which respond to or may be triggered by more or less complex groups of sensation. Their output finally converge on a "super neuron". The theory based on the schema hypothesis, on the other hand, stresses the fact that neurons continuously establish interactions and that the brain accumulates schemata which govern motor behavior by means of "ensembles of neurons". The cells involved in the process produce sequences of directed motions. Together they are assumed to constitute a unit for the execution of motions without reference to any particular region of the organism. As is well-known, Konrad Lorenz assumes, for example, that schemata are assimilable into genetic innateness. Also Piaget (1971, p. 10) considers perception and acquired behavior as a manifestation of certain "functional possibilities or reaction norms of an organism".

For Kant (see E. Cassirer, 1922, p. 143), the schema is the product of the organism´s "ability of imagination". But thereby he refers to a synthesis of a variation rich experience which becomes unified.

Thus, there is no point-to-point sequential processing, instead the organism "knows" by means of a schema if it has been influenced by an event in the environment or if it influences the environment by causing an event. Also Kant clearly points out that imagination has in no way anything to do with a "picture" or an "image", which means that one has to keep separate the schema from the frame.

From the psychobiological point of view Head (1920, p. 605) makes clear that the

"... image, whether it be visual or motor, is not the fundamental

standard against which all postural changes are measured. Every recognisable change enters into consciousness already charged with its relation of something that has gone before...".

From Gibson´s point of view, perception depends on the detection of invariants over time which means that a scene displayed by a picture cannot be reestablished. Further, a picture displays the perspective of the scene but cannot enhance the reality of that scene. Therefore, Gibson (1977, p. 284) points out that the separation of invariant structure from perspective structure is of fundamental importance in the study of the individual´s reactions to an event. Gibson´s reasoning is in line with Russell's (1948, p. 269) that "the analysis of physical entities into structures of events and even events... may be regarded with advantage as having a structure".

By means of schemata, desired events in the future can be anticipated and represented in the brain. When schemata become functional (operative), autoregulation is possible and patterns of behavior can be generated and tested against "represented" future states.

Thus, the schema is the cognitive device for successful apprehension of objects or events. In this sense, schemata can be conceived as an a priori determination of time or, as Gibson aptly expressed the state of affairs, as "formless invariants over time".

Also for Grossberg (1980, p. 6) is "the structure of an environmentally adaptive tissue a dynamic schema which develop through the influence of experience". But maintaining feedback is achieved by "the variety of experience".

Russell asserts that events must possess structure and that the structure of an event must contain certain familiar properties,

otherwise one cannot perceive an event. This implies that the organism must have developed a neural structure which is able to "experience" only one world instead of an ongoing flux of sensations. Without the ability to perceive "reflectances" of objects and events, as Gibson states, nothing would be perceived as permanent.

The difficulty with event structures, however, is that events are transient in nature and cannot easily be repeatedly exhibited. This circumstance influences possible ways to imagine how future events might influence a present state.

From a psychoecological viewpoint (see Bierschenk, 1978, 1980) events are regarded as necessary counterparts in the analysis of cognitive models which govern the way in which an individual perceives the structure of conserved events (i.e. on videotape). Both are important in the description of significant properties of developing processes in human interaction.

The unifying aspect in the theoretical discussion from Kant to Gibson seems to be the agreement that the schema is the conceptual tool which integrates temporarily separate events. For Kant (see E. Cassirer, 1922, p. 143), a cognitive structure has to be applied over time (i.e. to be transcended) otherwise it would not be possible to tie categories with phenomena. In fact Piaget (1971, p. 254) makes the same statement when he writes:

"The roots of such schematism are innate, whichever way you look at them."

Kant has tried to analyse the concept of "knowledge" (i.e. what is in experience) and thereby arrived at the conclusion of "schemata" as mediators between category and appearances or meaning and being.

Exactly the same point of view emerge from Piaget´s analysis of the concept of "knowledge" (i.e. the origin of experience) when he (1971, p. 153) writes:

"The outstanding characteristic of cognitive organization is the progressive dissociation of form and content."

Further, Piaget (1971, p. 306) carefully points out that "... knowledge cannot be reduced to authentic learning in the sense of being drawn from experience of the external world...".

On the other hand, Gibson (1979, p. 3) seems to point out that he does not build at all on a Kantian approach, although this appears to be a misconception by Gibson himself. Kant argues in the same way as Gibson does when he makes sure that to him (Kant) external experience of objects is immediate and not mediate.

In addition, Kant, Piaget and Gibson assume that the perception of external objects is possible only by means of a space-time coordinate, although Gibson has in mind terrestrial environment, processes, changes and sequences and not, as is the case of Kant and Piaget, Newton´s concepts of space and time. Kant claims, as Gibson does, that the objective reordering of extracted information (i.e. the subjective succession of cognition) actually is a synthetic reorganization which is an a priori act of human understanding. It seems also unwarranted to accuse Kant of having developed a "rigid and resolutely static framework" as Piaget (1971, p. 314) does.

However rigid and static or flexible and dynamic a notion of "schema" the authors had in mind, it must be granted that human beings act on "implicit cognitive models" and that their actions, especially their verbal behavior, express a high degree of schematism and struc-

turization. Cognitive assimilation is, according to Piaget, the "subject´s power of coordination" in interaction with the "data of experience and environment". In Kant´s words, the "causal ordering of cognition", or in Gibson´s words, that of the "information picked up", is an intellectual act brought to experience or information and not derived from it. This is the interactive approach captured by Kant´s concept imagination ("Einbildungskraft").

5. REFERENCES

Abelson, R.P. The structure of belief systems. In R.C. Schank & K.M. Colby (Eds.). Computer models of thought and language. San Francisco: Freeman, 1973. Pp. 287-339.

Bartlett, F.C. Remembering. A study in experimental and social psychology. Cambridge: Cambridge University Press, 1932.

Bierschenk, B. Simulating strategies of interactive behaviour. (Studia Psychologica et Paedagogica, No. 38.) Lund: Gleerup, 1978.

Bierschenk, B. Psychoecological foundations for a representation of highly abstracted information. Paper (The Center for Advanced Study in Theoretical Psychology, University of Alberta, Edmonton, Canada), 1980.

Bobrow, D.G. & Winograd, T. An overview of KRL, a Knowledge Representation Language. Journal of Cognitive Science, 1977, 1, 3-46.

Bregman, A. Perception and behavior as compositions of ideals. Cognitive Psychology, 1977, 9, 250-292.

Cassirer, E. (Ed.) Immanual Kant´s Werke (Vol. 2). Berlin: Bruno Cassirer, 1922. Pp. 74-147.

Cassirer, H.W. A commentary on Kant´s critique of judgment. London: Methuen, 1970.

Craik, K.J.W. The nature of explanation. Cambridge: Cambridge University Press, 1943.

Gibson, J.J. The senses considered as perceptual systems. Boston: Houghton Mifflin, 1966.

Gibson, J.J. The ecological approach to visual perception. Boston: Houghton Mifflin, 1979.

Gippenreiter, J.B. & Romanov, Y. A method of investigation of the internal form of visual activity. In: R.B. MacLeod. Perception. Essays in honor of James J. Gibson. Ithaca: Cornell University Press, 1974. Pp. 227-249.

Head, H. Studies in neurology. London: Oxford University Press, 1920.

Holst, E. von, & Mittelstaedt, H. Das Reafferenzprinzip. Naturwissenschaften, 1950, 37, 464-476.

Johansson, G. Projective transformations as determining visual space perception. In: R.B. MacLeod. Perception. Essays in honor of James J. Gibson. Ithaca: Cornell University Press, 1974. Pp. 117-138.

Kant, I. Prolegomena (The Paul Carus translation extensively revised by J.W. Ellington). Indianapolis: Hackett Publishing Company, 1977.

Melzack, R. & Wall, P.D. On the nature of cutaneous sensory mechanisms. Brain, 1962, 85, 331-352.

Minsky, M. A framework for representing knowledge. In: P.H. Winston (Ed.). The psychology of computer vision. New York: McGraw Hill, 1975. Pp. 217-277.

Newell, A. & Simon, H.A. Human problem solving. Englewood Cliffs, N.J.: Prentice-Hall, 1972.

Oatley, K. Perceptions and representations. The theoretical bases of brain research and psychology. London: Methuen, 1978.

Piaget, J. The origins of intelligence in children. New York: International Universities Press, 1952.

Piaget, J. Biology and knowledge. Chicago: The University of Chicago Press, 1971.

Piaget, J. Behavior and evolution. New York: Pantheon Books, 1978.

Russell, B. Human knowledge. London: George Allen & Unwin, 1948.

Schank, R.C. & Abelson, R.P. Scripts, plans, goals and understanding. Hillsdale, N.J.: Erlbaum, 1977.

Smith, N.K. A commentary to Kant's critique of pure reason. The MacMillan Press, 1979.

Szentagothai, J. & Arbib, M.A. Conceptual models of neutral organization. Neurosciences Research Program Bulletin, 1974, 12 (3), 307-510.

Uttal, W.R. The psychobiology of sensory coding. New York: Harper & Row, 1973.

Weizenbaum, J. Computer power and human reason: From judgment to calculation. San Francisco: Freeman, 1976.

Winograd, T. Understanding natural language. New York: Academic Press, 1972.

Young, J.Z. Programs of the brain. Oxford: Oxford University Press, 1978.