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ABSTRACT

The first of three articles on the ways in which people formulate their observations, this paper considers the basic assumptions of both syntactic and paradigmatic models of cognition and their applications in natural (i.e., human) and artificial (i.e., computer) information processing. The analysis begins with background information on the nature of inventions and discoveries, the nature of perception, and modelling of the process of concept formulation. The differences between syntagmatic and paradigmatic processing models are then outlined, and the principles of operationalization, simulation, cross sectional analysis, and cross level analysis are examined as they are applied to models. The role of context in examination of languages is also discussed. A list of 38 references is appended. (MSE)

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Abstract

A common way of looking at cognition builds on the generation and representation of knowledge based on syntactic models. Above all, in connection with computer applications, it is proposed that the syntactic models are of significance for research on language and cognition. In the representation of a cognitive phenomenon, language plays the central role. Therefore, a contrasting discussion of the basic assumptions of both syntactic and paradigmatic models is the starting point of a method development that differs markedly from the common view of cognitive functions. This is the first of three articles about the way in which people formulate their observations.

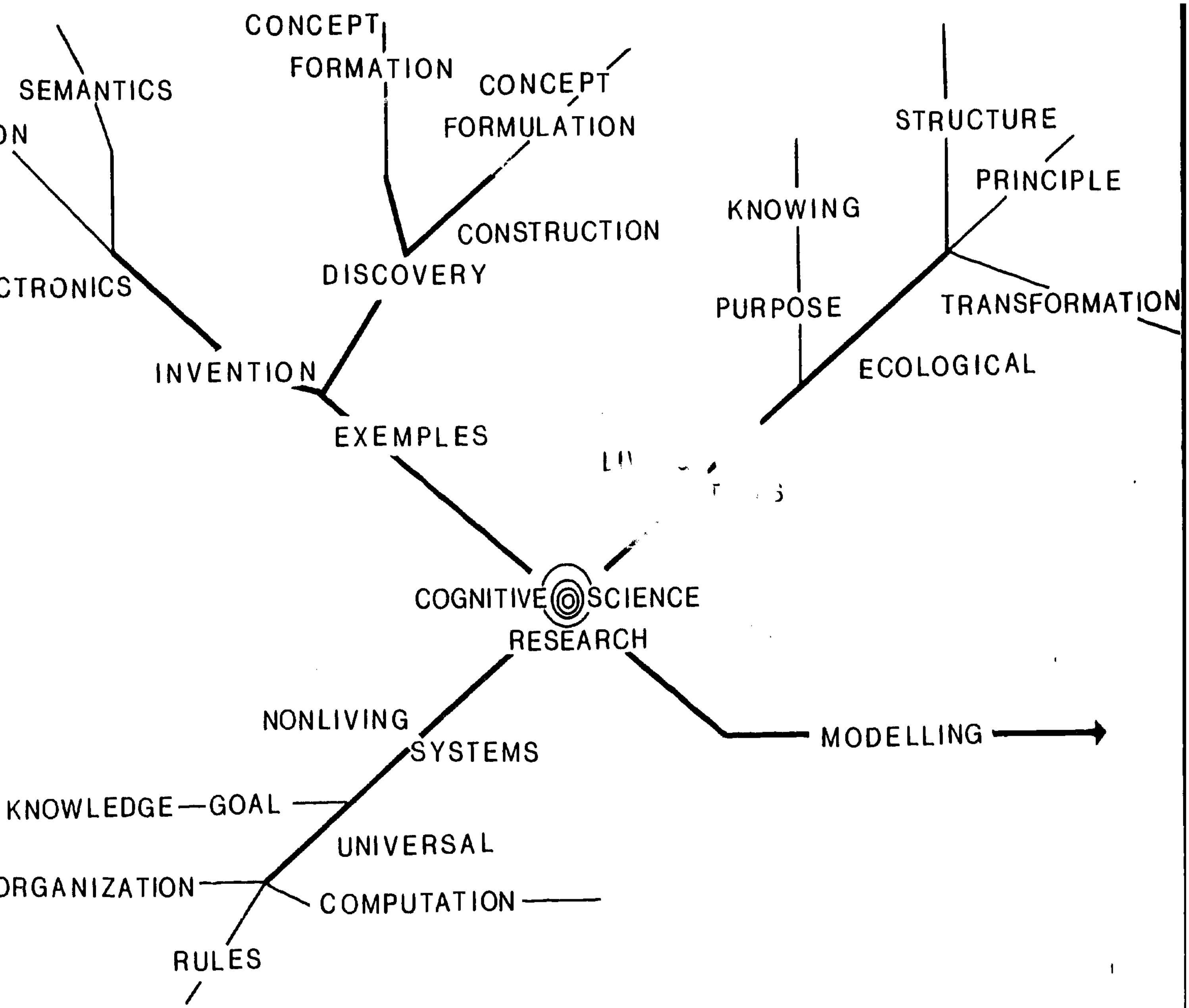
Essential to all cognitive science research should be to include physical variables if it shall be capable of providing realistic knowledge about (1) the theoretical development of living and nonliving systems, (2) models in which cognition can be reflected, and (3) how the models can be operationalized. The focus of cognitive science research is on the brain, consciousness, and knowledge. Language has the central function of bringing about information of cognitive nature for both impression and expression. A study of language as an intentional act and not only as a direct description of discrete (functional) states means that language is regarded as the key to a scientific understanding of consciousness and knowing. This orientation is presented in Figure 1. The phenomenon of cognition is conceived as a product of dynamic change within the field of tension between the formal and the factual sciences. Cognition is, therefore, restricted neither to design nor to a manipulation of intelligence variables.

Examples of Inventions and Discoveries

New communication systems have led to a change in the flow of information, which is to be seen in its form of representation and degree of abstractness. Advanced electronic text processing is internationally expanding. Computerized text processing includes everything from interactive language translation to registration of documents. Characteristic of these systems is the formalization of a priori selected linguistic attributes in purely logical terms and the handling of complexity problems at the construction of language databases, that is data organization and retrieval. It is important, therefore, that cognitive science research

(1) emphasizes the understanding of the conditions of information processing within living and nonliving systems respectively, and
(2) draws attention to the fact that learning and intelligence as problems of research differ fundamentally from consciousness and knowing.

The specifically cognitive aspects of a research problem are not restricted within disciplinary boundaries, a circumstance that has



. Cognitive science at the cutting edge of living and nonliving systems been recognized through some ongoing scienti[illegible]operation across disciplines (Miller & Gazzaniga, 1984). However, [illegible]s cooperation has not come about as a result of similar methods and techniques but merely because of the common inter[illegible] among scientists to formalize (logical calculation) the infor[illegible]l phenome[illegible] Nelson (1982), for example, writes that " the logic[illegible] mind " is nothing but a system of recursive rules embodied i[illegible] neural [illegible]stem. He aims at proving the hypotheses that log[illegible] neu[illegible] networks, grammar, electronic circuits, and cognit[illegible] can be explained [illegible] interpreted with John von N[illegible]957) recursive function theory in mind, the founda[illegible] computer. A more experimental approach representing lear[illegible] taken by Papert (1980) who with reference to Piage[illegible] tries to map out the logical form that operates in learning mathematical concepts. The development of thinking in a cognitive science perspective has been presented by De Mey (1982) with the purpose of illustrating consciousness and knowledge. But Newell and Simon (1972), above all, [illegible]entrated their efforts upon a logical calculation of the learning process through algorithmization of problem solving strategies. This effort is based on the assumption that intelligence is the characteristic aspect of thinking, the validity of which the authors have not tested experimentally, however. Further, associations of memory are supposed to be a sufficient condition for a sequential organization [illegible] cognitive operations. Some measurement of an organism's ability to [illegible]rganize single mental operations so that they correspond to the organization required by a certain problem has not been the aim. Instead, computerized instructions denote that certain cognitive operations have to be activated in a prescribed order.

The natural and artificial context respectively of information processing sets the fundamental frame for an investigation of which strategies are used by adults when they formulate themselves verbally. During centuries, much work has been done concerning the correct use of language, partly as grammar writing, partly as the establishing of conventions for text creation and interpretation. It is obvious from research literature, however, that there is a general skepticism towards pure syntactic or semantic approaches as basis for developing theories of language and language use. The same holds for the mathematical and metamathematical approaches developed for the purpose of designing models for representing internalized procedures.

Inventions

The progress within electronics has led to the growth of the field of Artificial Intelligence (AI). Along with the computerization protocols have been constructed to specify an electronic coding of information at various levels of representation.

Vision. The term computer vision is used to denote those research efforts dealing with the building in of a visual system into the computer. One protocol developed which has been internationally accepted is " Picture Description Instructions " (PDI). It means, in short, that graphical characters are displayed on the TV-screen by instructions to a terminal to produce geometrical primitives. These are (1) point, (2) line, (3) arc, (4) rectangle, and (5) polygon. They are used to construct " images " on the screen. The cognitive functions assumed are identical with computational functions used in the identifying and grouping of lines (Winston, 1975), and in the discrimination and association of " features " (E.J. Gibson, 1969). The laws of electronics prerequire no perspective, only a multiplicity of viewpoints.

Semantics. Computational semantics requires rules for the presentation of alpha-numeric characters. The rules are defined in various internationally accepted protocols. By processing characters and strings of characters, systems of words and meanings are built up, under the assumption that it is primarily the organization and handling of different kind of lists that are associated with the analysis and description of text. AI researchers have begun to study language with the emphasis on programmability. They presuppose that the existence of an algorithm would be a sufficient basis for an explanation of the phenomenon of natural language (Schank & Colby, 1973; Lehnert & Ringle, 1982). The methods and techniques used within AI are based on syntagmatic processing, which implies well-defined texts, since they are to function as base material onto which a formal-logical machinery can operate (Miller & Johnson-Laird, 1976). The competence (=intelligence) of the system is defined by means of the following four representational principles: (1) creation of facets, (2) construction of class relations, (3) development of semantic nets, and (4) organization of matrices. With their concentration on nonliving systems, the AI researchers seem to assume that an organism's ability to perceive significant aspects in their environment rests on its ability to represent these aspects internally (B. Bierschenk, 1984b). Therefore, they ask this somewhat sterile question (Dresher & Hornstein, 1976): Are there properties and property relations in a natural language which may be organized so that a machine can carry out certain specific tasks within a well-defined frame?

Discoveries

Inventions, as a rule, have their origin in answers that science has been able of giving to fundamental questions, but discoveries put new facts to our experience and knowledge about the world. When the essential dimensions are caught in a model and this is tested in realistic situations and under controlled conditions, scientific discoveries can be made. Cognitive science discoveries should be made around two natural phases, one developing and one constructive. Research on the concept of development concerns the nature of cognitive development (Pittenger & Shaw, 1975) and the particular ability to perceive and identify form (Andersen, 1975). Human information processing is based on the ability to discern reality from symbols of it. How this ability grows has been studied by Piaget (1963), who has published his results in his probably most characteristic work " The origin of intelligence in children ".

Any research of corresponding intensity on the concept of construction has not been reported in the international literature. While concept formation is connected with the denotative capacity of language (nominalization), construction (formulation) refers to the creative process characterized by an ability of differentiating between form and function and to express this with the instruments of language (Bierschenk & Bierschenk, 1984a, b; 1985; Bierschenk & Bierschenk, 1984). Thus formation is followed by formulation. Concept formulation means to give expression to both complexity and the structural relations of concepts in such a way that familiar concepts are reproduced or new ones emerge. To study concept formulation processes so that strict and at the same time practically useful methods for the description and analysis of adult language become available must be regarded as an extraordinarily important research task, especially with respect to the significance attached to the integration of electronic information processing systems into our every day life.

Nonliving and Living Systems

Information processing within " physical symbol systems " (Newell, 1981) builds on artificial electronic processes. Theories about universal information processing are presented as axiomatizable classes of statements in a formally clarified language. Since natural laws are characterized solely on the basis of logical form (Simon, 1981), the world is known a priori, and since it is rule governed, man gets his knowledge of it by mathematical computations (Wigner, 1969). The cognitive process is studied as if the aim was to find out the computational power of the brain and how this could be represented with geometrical formalism and inference logics (Pearce & Cronen, 1980).

The subsystems are arranged by an organization of elementary facts (databases) which function as a nonanalyzable unity, determined to be valid for a well-defined domain of knowledge regardless of time. The aim of information processing within "physical symbol systems " is to generate knowledge systems by means of models with ever more powerful computing capacity. Knowledge is a normative organization of facts, according to these theories, facts which can be represented in universally valid trees (" knowledge trees ").

Two main lines may be discerned within research on human information processing. Both express the need for a precise characterization of psychological processes: The psychophysical approach put forward by Fechner (1801-1887) and the ecological physics developed by Gibson (1904-1979).

Is reality perceived as a number of primitives which are processed in information channels independently of each other? Are sensory stimuli stored in an associative memory? Could it be that properties of what we observe are perceived directly and without mediating, organizing processes? Psychophysics aims at answering these and similar questions in trying to establish criteria for (1) at what stage in the development of an organism a memory can be demonstrated, (2) at what place it exists in the brain, and (3) how it operates, that is which constraints in capacity exists (B. Bierschenk, 1984a), and also (4) what influence these constraints have on behaviour (B. Bierschenk, 1984b).

Information processing based on ecological physics takes its point of departure in the richness of information in light. The theory is founded on the assumption of an organism's ability to perceive ecological invariants directly (Gibson, 1979), which means that it takes into account the principles of invariance or symmetry structuring the natural laws (Wigner, 1967). Techniques for transformation are basic to the understanding of both perceptual and cognitive processes as well as the concept of invariance (Shaw, McIntyre & Mace, 1974). Structure is the concept used to characterize coherent systems, subsystems or components in a three-dimensional space at a certain given point in time. (One example of an empirical definition of the structure concept is to be found in Helmersson, 1985.) Within this line, knowability and what specifies knowable objects is studied through empirical experiments. For this purpose observations are systematized which indicate components of higher order in perception and verbalization.

Knowing emerges at the moment of change, which makes it a dynamic phenomenon. Change is the fundamental characteristics of all organismic activity. The basic theme of the ecological approach is that permanence and change are complementary to each other. This implies that knowing could be described by means of " broken symmetries " (Kelso & Tuller, 1984). Thereby, knowability would be conceived as something that emerges from a cooperative process. As such is could be assigned neither solely to the organism nor to the environment.

Modelling

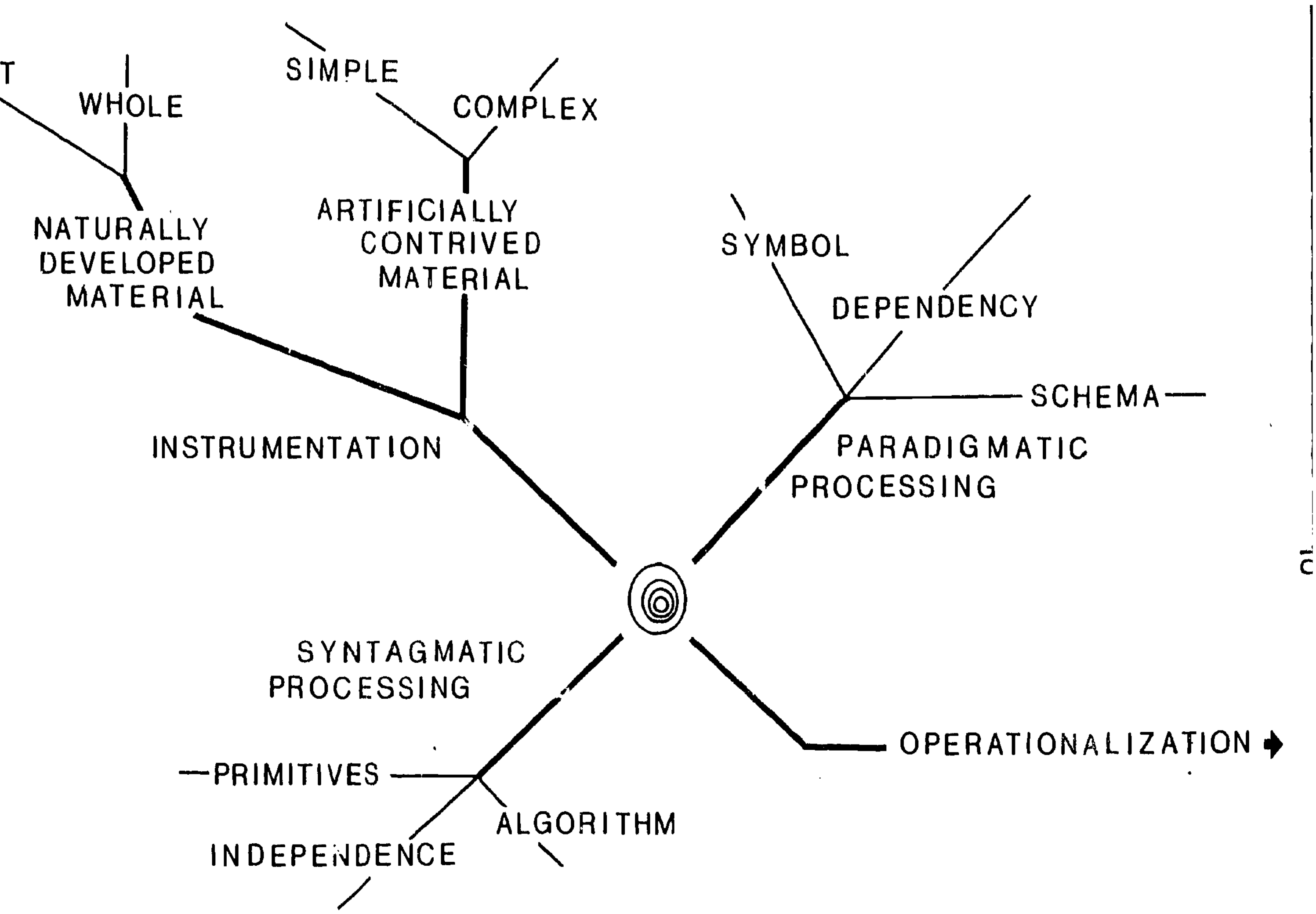
For a long time, research has tried to find what behaviour or action rules are basic to both single individuals and entire populations. The central ideas within different theoretical lines such as empirism and functionalism have been converted into models, whose expression may be a simple paradigm or a complex system. A model for the output of information processing based on an entire action pattern will, for example, be differently realized than one based on differentiated strategies.

Information processing as communication between systems is traditionally modelled as a classifying procedure aiming at isomorphic states between the systems after the transmission of a message. This view on communication may function as long as the treatment of a subject area does not require cooperative action strategies. Modern developments regard intermediary functions as important (I. Bierschenk, 1980), which allow transformation instead of transmission.

To create models which are capable of connecting language with explainable informational hypotheses requires, with reference to Figure 2, a discussion of the nature of the instrument, since its properties decide whether the communication process will become artificial or natural.

Instrumentation

The goal with an instrumentation is to be able to detect the structure of the information. That drawing a line between natural and formal languages as regards their function as cognitive instruments may be troublesome is obvious by the circumstance that AI researchers almost exclusively are grounding their conclusions about the cognitive significance of language on compositions (artificially composed sentences) and sentence complexes with the idea that these are natural only because words and grammar happen to coincide with English, for example. They overlook the fact that the functions of



re 2. Modelling

a sentence are defined by the relations between at least three constitutive components.

The concepts in a natural language material may have identical organizational (graphic) representation although not the same structure. If the structure of a concept is changed in such a way that it also changes the expression in a linguistic sense, then there is a change of concept. Consequently, the explanation of the concept formulation process requires a reproduction of both the organization and the structure of the concept. Typical of artificially demarcated or designed material is that only its surface features can be processed in the form of simple and compound patterns. Unlike text compositions there are in natural materials structural connections, which are not composable by linking of surface features.

Syntagmatic Processing

The syntax of natural language is conventionally defined as a formal mechanism generating sentences out of a set of discrete entities, which differ ~m entities that are not sentences. Thus a sentence consists of . number of alphabetical strings of characters (words) which are regarded as units in a sentence system. With respect to the formalism of language, the sentence units are usually classificationally differentiated.

Syntagmatic models prerequire the processing to be executed with rules for summative combinations of unambiguous, simple and discrete units which are structureless as well as timeless (primitives). This primitivization means that the units, like sensations, can populate a dimensional space (consciousness). The concept of independence is fundamental within this model type, since order relations of the objects must be defined in a way that the objects behave independently of context and monotonously to one another (Pfanzagle, 1971). Monotonous order relations are the basis for the matching processes required in a study of repeated response behaviour.

Algorithms based on linear assumptions combine the primitives associatively. Therefore, the objective knowledge consists of mathematical-logical statements about associations between variables. Well functioning algorithms for storing and retrieving are used as theoretical explanations of a given verbal expression (Boden, 1977; Dreyfus, 1979).

Paradigmatic Processing

Unlike the syntagmatically oriented research (with or without computer), research directed towards theories of living systems works with models that build on selection and abstraction. In this kind of language processing no monotonous transformations or linearizations are assumed but, instead,schematizing transformations. The fundamental assumption of the schematizing process is a cooperative dependency (functional synergy) between units, which are here denoted symbol in correspondence with the definition in Polanyi and Prosch (1975). Processing based on symbols prerequires that transformations are taking place during the course of verbalizing, which at the same time preserve the empirical ground and continuity. The relations formed at this process result in functional change in the context. The relational system is a cognitive unity, a schema, which partly may change with the number of processings, partly may influence the processing itself. This type of text processing implies that criteria for the logics of irrational behaviour can be set up, provided that the responsible agent is known. Thereafter, rules for a satisfactory behaviour can be tested and algorithmatized.

Operationalization

The characteristics of a nonliving system may sometimes be difficult to specify. On the other hand, it is a well-known fact that invented systems, like computers, show a " behaviour " which is clumsy and insensitive to information from the environment. When, however, a system in a consistent way can respond to environmental phenomena it has established a behaviour- or action model that efficiently and economically handles an information rich environment. For an interchange with one's environment, intention and action is needed, which, on their part, call for the existence of an internal structure and a self-protective ability. By using demonstratively definable operations (see Figure 3), that is simulation and laborative testing, we are able to discover the way in which experience and model covary.

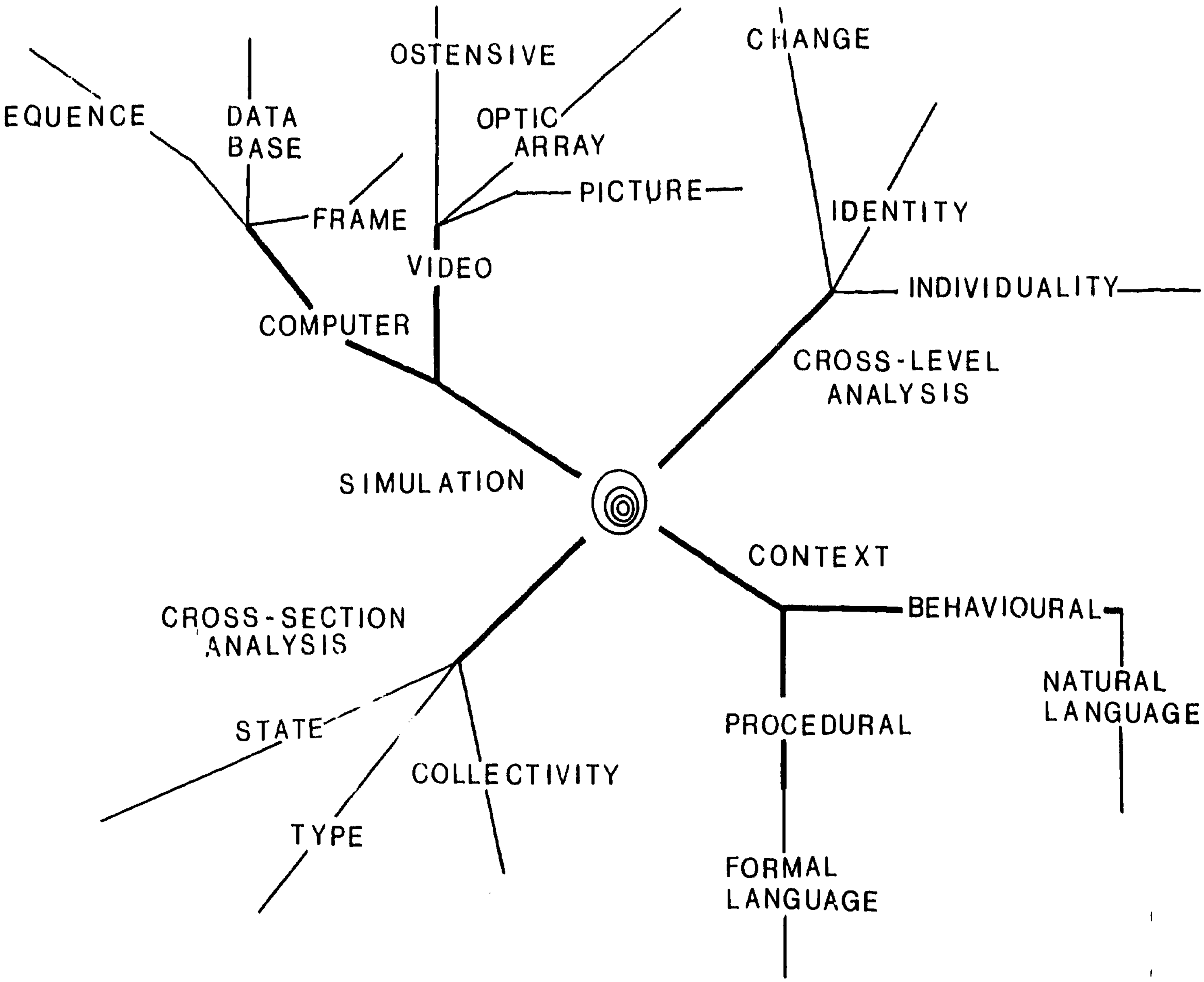


Figure 3. Operationalization

Simulation

Simulation presupposes an initial specification of a problem, more or less exhaustively. Moreover, a behaviour- or action model is required. The quality of the simulation increases with augmented contextual information and the number of action alternatives. Computer simulations require a formal language of specification and a set of procedures which can be adjusted to a defined behaviour model. Further, a database is needed. Information is stored in so called frames whereas sequences of operations and screen layout are specified by means of scripts.

Video recordings are manifest representations which always imply some loss of information, since they represent somebody else's (other than the viewer's) visual field. A picture represents a scene within an optic field containing similarities with natural visual fields, but does neither coincide with nor reconstruct reality as a whole (the original visual field).

Cross Sectional Analysis

The term section denotes some kind of spatialization. If singularity is defined as the real basic unit within a collective, the analytic work presupposes the set up of classes and a definition of a state, that is class membership or not, by means of some kind of similarity measure. Language, on the other hand, has structure, which means that it is an integrated whole, and for this reason it is individual. A structurally analyzable unity can be identified with a concept and be categorized. But the crucial criteria of individuality is, according to Ghiselin (1981) a specification of part - whole relations with respect to functional cooperation (synergy). In this perspective the basic unit is neither (1) an organism nor (2) discrete units. In the first case autonomy would be mixed up with individuality while the second case would imply a confusion between classifyability and categorizability.

Concepts may be conceived as something static or dynamic. They are specified through operations distinguishing them from a background. The distinction should be conceived as an operation assigning to a concept its type value. Concepts demarcated in this way are static and thus classifiable. There is no need for posing questions about the origin of such concepts and they may have a nominalizing function. If a concept is defined as something categorizable, some more requirements on the distinguishing routines should be added. These concern the relations between the components of the concepts. The components namely specify the subject within which the concept may be conceived as a name giving identity to a phenomenon, an organism, a population or species, and within which the concept may change.

Cross Level Analysis

Systems defined by structure have identity. It is the point of departure for working out natural groups or Gestalts from a texture. This requires an analysis of levels for the determination and description of behaviour change. Change is here defined as

(1) change in structure without loss of the system's identity (change of a state in the individual)

(2) change of both structure and organization resulting in loss of identity

When identity is lost, the result is either a negative disintegration (=dissolvement) or a positive disintegration (a new individual is formed).

Context

Until recently scientists have denied the existence of cognitive phenomena (Bateson, 1979; Wigner, 1967). With the success of mechanical physics in describing macro- and microcosmos, researchers in psychology have believed themselves to be able to formalize psychological phenomena by means of lens models (Brunswik, 1956; Sommerhoff, 1950) and algebraic manipulations. Reasearchers who assume a noncosmic context in the description of a cognitive world have to take naturally constraining factors into account (Rosen, 1978).

Shall cognition be conceived as procedure, a control governed language is needed for the executions of the operations. The statements about a hypothetic world can then be formulated by inference logics and the values for the criteria " true " or " false " be computed by a program. The psychological phenomena represented by programs must presuppose that the information is carried by an α- or β-language according to the relations presented in Table 1.

Table 1. Type of information and stepwise change of level of representation

Language	Explanative level	Representation	Centre	System type
α	electro-chemical states (analogous, discrete)	spatial organization	exocrine nerve fibres	chemical molecules DNA → RNA → proteine ⇌ key — lock paradigm
β	organization	binary relations	motoric brain functions	neurons, synapses; fish, bird, mammal built-in programming
γ	structure	schema	symbolic brain functions	humans primates ? thesauri

The interpretation of Table 1 should begin with the identification of type of information represented by its carrier (the language). The representation of the information requires an alphabet, which in the case of an α-language consists of two letters. Its explanation takes place by means of different types of circuits containing well-defined and explained patterns for transmission of electro-chemical or electronic signals between various components within a system. For example, biological transmission of chemically coded information takes place through molecules. Two-letter coding (α-coding) implies that electro-chemical processes are characterized by a bound or unbound state, on — off respectively. This can be symbolized with the following letter combinations (++, --, +-, -+). The key — lock paradigm is another example of an α-coding. Explanations according to this paradigm can be found in programmer handbooks which have the α-function with respect to various machine configurations.

A β-language implies that particular formulas have been interpreted as letters that are organized in strings. The organization may differ with respect to its logical design. A certain organization of formulas may be more appropriate for a particular system compared to another organization. This is easily conceived through the fact that different programming languages vary as regards the aspects or variables of interest to the process in a certain system (machine). On the β-level, the response of a system is consistent to its programming. The requirements for β-coding are that a formula can be changed intentionally from one state to another and that no formula may change unintentionally. A further requirement is that the position of a formula must be identifyable. β-coded information varies in its logical complexity, which means that information is grouped and organized with special interrelations holding between the groups. Binary relations may be used to represent the organization by means of predicate-logical models. β-coding has been studied through behavioural analysis of simple multicellular animals. These studies show that action changes through experience implying associative processes in the neuronal cells, ganglia, or net. Associative learning has also been studied in fish, birds, and mammals. It seems that the cortex of these organisms is taking part in the learning process but is relatively unimportant compared to the role of the retinal system or other parts of the organism. Moreover, it is as yet undecided if associative learning takes place on the level of the cell. What is known, on the other hand, is that association is absent on the level of the organ.

The schematizing functions of a γ-language is marked by its unique capability of preserving symbolic behaviour. γ-coding requires that invariances can be observed and conveyed in symbolic form. In contrast to the α- and β-levels, the γ-level is behaviour governed.

This means that every behaviour carries on a structural unity represented by the bond holding between the agent and the object for his actions. Thus, to the extent that an agent (A) is able to distinguish between his regularized behaviour (aO) and its symbolic expression, measurement can be carried out to account for the perspective difference between behaviour and symbol (Aa (AaO)). Shall information be represented in a γ-language, this presupposes that a symbolic language has been developed. That which is regularized or invariant under transformation builds on cooperative interacting components. To the extent that a technical system or a thesaurus consists of such components, this means that compiling or explaining algorithms have been developed. The more common state of affairs is that a programmer or algorist has this function. Therefore, the criteria for a satisfactorily presented behaviour in a γ-language can only be set up with knowledge of the realistic agent.

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