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# STAGES OF MENTAL DEVELOPMENT: WHERE TO LOOK?[1]

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**Abstract.** This article examines a question of stages in mental development. Two approaches to the study of development, 'modular' and 'structural', are differentiated. These approaches seem to contradict one another. We suggest that there is a need to differentiate complementary levels of analysis, each with specific objectives and methodologies. Contradictions between theories of development do not emerge because some theories are "wrong", but because different levels of analysis are confused. So, universal and general stages of mental development can be revealed at one level of analysis, at two other levels the development can be characterized as a continuous change or a quantitative growth, respectively. Following these ideas, a new definition of the stages of mental development is proposed along with theoretical differentiation of the first three stages of development. Empirical evidence for supporting the theoretical model of stages is also discussed.

The problem of general stages in mental development is a long-standing controversial issue in developmental psychology. Empirical evidence, collected over the last decades, has revealed that mental development is not as general-stage-like as Piaget and the majority in the field once thought (Flavell 1982, 1992). Controversies within stage theories led to the formulation of many different theories of development (see Sincoff and Sternberg 1989, for a review). Some of the researchers (e.g. Robbie Case and Kurt Fischer) have presented new stage theories, others (e.g. Robert Siegler) have conceptualized the development as progression over subsequent partly overlapping vawes, and some theorists (e.g. John Flavell) characterize the development as a quantitative growth.

However, it is possible that the same phenomenon may seem qualitatively different when analyzed at different levels of generality (Duke 1994, Munro 1992, Scarr 1992, Teitelbaum and Pellis 1992). Thus, a conflict between developmental theories may result when different levels of analysis are confused. Such an idea leads to the question posed by Flavell (1982:9): "Maybe there really is something general-stage-like about the child's cognitive development, if only we knew how and where to look." The present article is an attempt to answer that question.

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The article has four objectives: (a) to describe two approaches to the study development, 'structural' and 'modular', (b) to analyze conceptual difficulties connected with stage theories, (c) to propose four levels of analysis of mental development, (d) to propose a new definition of stages in mental development and to differentiate theoretically the first three stages of development.

## 1. Structural and modular views on the development

In general, two views on the mental changes with increasing age and experience, 'modular' and 'structural', can be differentiated (see also Valsiner 1992a, for analogous distinction).

### *1.1. A 'modular' view*

According to the view which we call 'modular', the mind is in some sense compartmentalized or 'modularized' (cf. Wellman and Gelman 1992). If such a view is transported into the realm of developmental psychology, the development is conceptualized as did, for example, Fodor (1972:93):

> *[...] the child is a bundle of relatively special purpose computational systems which are formally analogous to those involved in adult cognition but which are quite restricted in their range of application, each being more or less tightly tied to the computation of a specific sort of data, more or less rigidly endogenously paced, and relatively inaccessible to purposes and influences other than those which conditioned its evolution. Cognitive development, on this view, is the maturation of the processes such systems subserve, and the gradual broadening of the kinds of computations to which they can apply.*

Thus, according to a modular view, development is nothing but a quantitative growth in information-processing capacity and in domain-specific knowledge (see also Flavell 1985, 1992, for similar ideas). This line of thought leads to questions *what* children are able to do or *what* they know relative to adults, but not *how* adults and children differ (cf. Valsiner 1991).

### *1.2. A 'structural' view*

According to the other, 'structural' view, mind should be described as a structure of elements in specific relationships (cf. Koffka 1950, Köhler 1959, Piaget 1970, Vygotsky 1994, Werner 1957, 1973). Structures have several important characteristics. First, a structure is a qualitatively new phenomenon, which does not automatically follow from the simple sum of its elements. New qualities emerge only when specific relationships between elements are established.

The next two characteristics of structures are differentiated by many theoreticians. For example, Köhler (1959) differentiated between dynamic and topographical factors in structures, Lewin (1935) differentiated psychodynamic and topological descriptions of a structure, and Koffka (1950) differentiated processes and conditions.

So, structures can be characterized by 'topographical' factors. Topographical factors exclude certain forms of function of a system and restrict processes to the possibilities compatible with topographical conditions. For example, a visual system allows to represent virtually an infinite number of objects we can see. However, all such representations are 'topographically', i.e. qualitatively constrained, they are only visual. There is another side of topographical constraints that we call 'dynamic' properties of structures. Even though all visual representations are only visual, the number of possible visual representations is not determined by topographical factors. Thus, there are many different possibilities that satisfy the constraints of a topographical factor.

The fourth characteristics of structures, and especially mental structures, concerns the relationships of structures with their environments. According to structural theories (e.g. Koffka 1950, Köhler 1959, Lewin 1935, Vygotsky and Luria 1994, Werner 1957, 1973) the influence between (mental) structures and their environments is bidirectional. It can be said that from a structural perspective, the development is not a unidirectional transmission of knowledge from an environment to a child (as a modular perspective to mind would predict), but a 'co-construction' of mind in dynamic interaction between the individual and the environment (cf. Valsiner 1994a, 1994b).

The fifth, topographical and dynamic properties of structures are interdependent (e.g. Köhler 1959). We propose that such relationship between dynamic and topographical characteristics is a mechanism of development. This idea is clearly defined, for example, by Munro (1992) who also differentiated two aspects of systems – structure and process. According to him 'structure' defines what a thing *is*, and 'process' what things *are doing*. It is important that "processes at any level *n* operate on structures at level *n-1*" and "Processes at level *n* have the potential to become structures supporting processes at level *n+1*" (Munro 1992: 117). Analogous ideas about relationships between activities (performance) and mental structures (competence) are expressed, for example, by Karmiloff-Smith (1990), by Thelen (1995), and by Vygotsky (1984).

Thus, if a system is able to develop (i.e. it is 'unstable' in terms of the Dynamic System theory – cf. Thelen 1995), then its actions may lead to a transformation of its own structure. The transformation of a structure, in turn, leads to changes in topographical characteristics of a structure. This principle leads to the sixth characteristic of structures that is called the 'orthogenetic principle' (Werner 1957, 1973). According to that, development proceeds from a state of relative globality and lack of differentiation to a state of increasing differentiation and hierarchic integration. It means that an organism's actions lead to differentiation of its structure so that distinguishable parts constitute the whole. Such differentiation, in turn, creates a possibility for integration of qualitatively new wholes.

To take a concrete example, Nelson (1988, see also Lucariello and Nelson 1985, Yu and Nelson 1993) has described a process by which children construct a taxonomically organized lexicon from a schematically organized knowledge base. According to Nelson children first form categories of objects that can be substituted for one another within 'slots' in events. For example, a child's clothes put on in the morning may sometimes be a T-shirt and shorts, and sometimes slacks and a shirt. All these clothes belong to the same category, because they are interchangeable in the child's 'getting dressed in the morning' routine. Thus, children first experience future superordinate categories in 'slots'. It happens during activities in specific repeated events, i.e. in a course of a dynamic 'process'. During this process 'slots' of objects that share functional properties differentiate from the structure of an event. After differentiation it becomes possible to integrate differentiated elements into a hierarchically higher level structure of taxonomically organized knowledge.

In sum, in a structural perspective, "development is the process of *structural transformation* that takes place based on an organism's interaction with its environment" (Valsiner 1989: 4, emphasis in original). Structures are qualitatively new wholes of elements in specific relationships. All structures can be described by two factors, 'topographical' and 'dynamic'. Topographical factors constrain qualitatively kinds of processes a structure may support, dynamic factors are characteristic of processes that satisfy the topographical constraints of a structure. When a structure is 'unstable', processes, i.e. activities of a structure may lead to differentiation and reintegration of elements of a structure so that a qualitatively new level of structural organization, and the corresponding new level of topographical constraints is achieved.

It is important that a structural view does not suggest that a mind cannot be understood as a system of 'modules' in some sense. The principle of differentiation says that the result of the differentiation of a structure is development of qualitatively distinguishable parts of a whole, 'elements' of a higher order structure. As such elements are qualitatively different, they can be viewed as distinct (even though interrelated) 'modules'. However, a structural view predicts that a modular approach to the study of mind is insufficient for understanding development because it does not study the mechanisms of change.

## 2. Conceptual difficulties with stage theories of development

'Modular' theories, that search for 'independent' modules of mind are essentially contradictory to stage theories. This is because the idea of stages assumes that at every stage of development different processes ('modules' according to a modular view) are interconnected, they share certain properties that make the mind a coherent whole of associated, 'dependent' processes. Correspondingly, stage theories have received serious criticism from a modular perspective. In the following sections we discuss the main problems with stage theories and show that such criticism cannot disprove the idea of general stages in mental development if the latter is analyzed in a structural perspective.

The 'modular' perspective has defined four main problems with the concept of stages of mental development. The problems are that of "circularity", "measurement sequences", "non-psychological character of cognitive structures", and the question of the role of learning unrestricted by stages.

### *2.1. The problem of "circularity"*

Brainerd (1978, 1993) proposed three criteria for the explanatory theories of stages to be legitimate. According to these criteria the target behaviors that change with age must be posited, the antecedent variables which are responsible for such changes that weld the stages into distinctive entities must be differentiated, and finally, the procedures whereby the antecedent variables can be measured *independently* of behavioral changes must also be specified. The last requirement is, according to Brainerd, essential to avoid circularity. Otherwise statements of the form "children do x because they are in stage S" become circular and mean merely "children do x".

The logic of such thinking is legitimate only when there is a linear and unidirectional relationship between reason (antecedent variable) and cause (changed behavior). In this case the reason and the cause remain "independent" and can be measured "independently". However, according to a structural position (e.g. Thelen 1995), there can be no "independent" antecedent variables, because each component in the developing system may be both cause and product. In other words, when elements that are "antecedent variables" of more complex structures, differentiate in a course of development, then after integration into a higher level structure their properties change according to the laws of a new whole. Thus, more complex structures are built from the differentiated less complex structures.

Nevertheless, the definition "children do x means children are in stage S" is insufficient for a structural view either, because it does not define a general type of behaviors that characterize a stage. Consequently, for defining a stage, another formula is needed. A stage in a structural perspective would be described by similarities among different behaviors in a same stage, i.e. by 'topographical' factors. The proposition can be formulated as follows: *"Children are in stage S, when they do x, y, z, etc., because x, y, and z are similarly constrained by a topographical factor [XYZ]". A characteristic "[XYZ]" should be "independent" of every particular behavior, because it characterizes all behaviors which have reached the same stage.*

### *2.2. The "measurement sequence" problem*

The other problem related to the question of stages concerns the invariant sequence of stages posited, for example, by Piaget and Vygotsky. Brainerd (1978, 1993) suggested that the invariant sequences, that have received the most empirical support, are trivial by-products of nesting the measurement operations that are required to assess individual concepts. It means that a measurement sequence exists between two stage-related concepts C1 and C2 whenever C2 consists of C1 plus some other things. The implicit solution to the problem from a 'modular' perspective is a *quantitative* growth, a quantitative increase in the capacity of a special-purpose computational system.

From a structural perspective every more complex structure is a result of differentiation and hierarchical integration of lower order structures. Thus, more complex structures necessarily include less complex structures. The difference with a modular perspective lies in the conceptualization of the relationships between more and less complex behaviors (and, correspondingly, structures). For structuralists, more complex structures are *qualitatively* different from less complex structures.

Thus, the problem of measurement sequence is not sufficient for a priori abandoning the idea of stages in the development. The idea of stages predicts that the performance of more complex (i.e. "nested") tasks characterizes different stages when the solutions to less and more complex tasks are achieved by qualitatively different means, under qualitatively different 'topographical' constraints. Therefore, for abandoning the idea of stages on the basis of measurement sequences criterion, it must first be demonstrated that 'C2' type of tasks are solved by qualitatively the same means as more simple 'C1' types of tasks. The formal presence of nesting, however, cannot be a sufficient criterion.

### 2.3. *"Non-psychological" character of psychological structures*

Brainerd (1978, 1993) demonstrated that cognitive structures, described by Piaget, are in fact formalizations of tasks' structures. It is probably true that there are problems with such formalizations in Piaget's theory. However, on the other hand, if there is no correspondence between the structure of a task and mental structures, there would be no way to solve the task. For solving a problem the problem must be "translated" into a system of mental representations. Thus, task and mental structures must be similar in some respect for the solution of the task to be possible at all. And the task of psychology is not to search for mental structures, which are independent [sic! – core of a modular view] of task structures. Rather, from this perspective, the task of psychology is to answer the question how humans (or organisms in general) build internal representations on the basis of the tasks, presented to them. Examples of this kind of theorizing are Brainerd's own "Fuzzy-Trace" theory (Brainerd and Reyna 1990) and a theory of Mental Models (Johnson-Laird and Byrne 1993).

Of course, it can be argued that the same tasks can be solved by different strategies (e.g. Brainerd and Reyna 1990) and, correspondingly, there are no direct relations between tasks' surface structures and mental structures operating in a solution of a task. However, the point is that even though a task may allow different solutions, all differently achieved "correct" solutions should be structurally isomorphic with the deep structure of a task. In terms of a structural theory it means that dynamic properties of task structures are topographically constrained. Thus, if such 'topographical' characteristics of task structures are defined, it should be possible to understand which kind of mental structures are involved in a solution of a task.

### *2.4. Stage versus learning*

Recent studies show that 3- to 7-year-old children are able to solve problems that were considered to be unsolvable under the age of seven. This is true, for example, for tasks of spatial perspective taking (Newcombe 1989, Newcombe and Huttenlocher 1992), distinction of mental phenomena from physical objects (Estes et al. 1989, Flavell et al. 1992), and the understanding of mental phenomena (Leslie and Thaiss 1992, Roth and Leslie 1991). Such findings seem to contradict the idea of stages, and actually also the idea of qualitative development, because the findings seem to show that young children are able to do qualitatively everything the adults can, but are constrained quantitatively (see also Brainerd 1993, Wellman and Gelman 1992).

However, such demonstrations of early competence are based on methodologies where the tasks are made easier by "stripping away *unnecessary* processing demands, and *removing complexity*" (Wellman and Gelman 1992:367, our emphasis). The same authors suggest that such less demanding and less complex tasks measure qualitatively the same processes as more demanding and complex tasks do in older children or adults. This conclusion is far from proven.

The problem is that the same tasks can be solved by different means, some more and some less complex structurally. For example, calculations with quantities less than 10 can be performed with numbers and with fingers (cf. Siegler and Crowley 1991). Both strategies may lead to correct answers. Calculations with billions, on the other hand, can not be performed with fingers but only with arbitrary symbols. Although in the latter case the numbers are bigger quantitatively, the operation is different qualitatively. Thus, the quantitative complexity of a task may interact with qualitatively different demands of a task, and, correspondingly, there are no "unnecessary" processing demands in the tasks of scientific study of mental development.

There is also another problem. Usually it is understood, that the emergence of stages is related to a particular age of a child. When a child is able to do something earlier than Piaget (whose theory is most criticized from this perspective) proposed, then the theory of stages fails. But the relationship to the age is only secondary (e.g. Piaget 1960, Vygotsky 1935). Stages should be defined only in terms of structural relationships between more and less complex structures. The theory of stages would fail when it is demonstrated that tasks which, theoretically, must be based on more complex structures can be solved earlier than tasks the solution of which must depend on less complex structures. The relationship with particular ages is less relevant here.

Certainly, there are relationships between brain maturation, which is related to chronological age, and mental development (e.g. Hudspeth and Pribram 1990, Kolb and Fantie 1989, Majovski 1989). This is because a living organism is a psychophysical unity, a unity where one has to expect a correspondence in mental development, and in physico-biological genesis (Werner 1973). But brain maturation is not the only determinant of behavioral development.

Anokhin (1975) in his analysis of the development of "functional systems" (i.e. structures) of animals and humans, demonstrated that when it is necessary to create a new functional system, the maturation of the brain is "heterochronic". According to Anokhin, "heterochrony" is a law according to which the growth of the structures of an organism depends simultaneously on genetic information, and on the demands of the environment (see also Gottlieb 1991 on discussion of a similar idea). He demonstrated empirically that some substructures of the later maturating regions of a brain may, under the environmentally posed needs, maturate earlier than adjacent structures. Consequently, gross measures of brain maturation are not always connected with functional development.

Thus, the age of a child is not an absolute measure of a stage of mental development, although mental development and chronological age are correlated (see also Stanton 1993). The only absolute measure can be the complexity of mental structures. It can be concluded that the idea of general stages of mental development can not be refuted on the basis of empirical studies of young children with tasks of decreased complexity unless it is demonstrated that structural demands are qualitatively the same for quantitatively more and less demanding tasks.

## 3. Problems with a 'modular' view

The difficulties related to the view on the human mind we call 'modular' had been analyzed by many authors over at least a century (e.g. Baldwin 1966, Koffka 1950, Köhler 1959, Plunkett and Sinha 1992, Teitelbaum and Pellis 1992, Munro 1992, Valsiner 1989, 1991, Vygotsky 1935, Werner 1957, 1973). We would like to analyze only one problem, important in the present context. The problem concerns the necessity to analyze all qualitatively changing phenomena, including human mind in their genesis, i.e. developmentally.

According to a 'modular' view the task of developmental psychology is the identification of modules in children. For understanding ontogenetic development, after the identification of 'modules' it is only necessary to follow their quantitative growth. However, such an approach does not solve the question where new modules come from, if they are independent of one another (as requires a modular solution to the problems of "circularity" and "measurement sequences", discussed above). The simple statement that "modules" are only "relatively" independent does not help unless it is demonstrated that the other side of the "relative independence", that is of "relative dependence", has been linear and unidirectional. In this case it can be proposed that the process A both determined the development of the process B, and remained unchanged in the process. Then it would be possible to measure processes A and B independently. But when it appears that the emergence of the process B induced also changes in its "ancestor", the process A, the change is, by definition, structural.

For example, several authors have suggested that there is a specific "module" for syntax. But how is it possible that syntax develops independently of words? In fact, the evidence points to structural relationships between the two: Words can be used without syntax, as do, for example, children at the beginning of language acquisition. Children's first words are not differentiated into classes of nouns, verbs, adjectives, etc. Differentiation into the classes is a complex developmental change (cf. Olguin and Tomasello 1993, Tomasello and Olguin 1993) which is achieved with the development of syntax (cf., Forbes and Farrar 1993, Gleitman and Gillette 1995, Naigles and Kako 1993).[2]

Thus, the utilization of words does not depend on the utilization of syntax at the beginning of language development. With the development of structurally secondary syntax, the properties of words change. Consequently, in this case there are no "independent" relationships between developmentally earlier "antecedent variables" and developmentally secondary processes. If the processes have such structural relationships, a modular view must explain how structurally dependent processes may develop "independently".

Since the requirement of "independence" is central to a modular view, it follows that the 'modular' criticism of the idea of general stages would be decisive only when the problem of developmental "independence" is resolved. Otherwise the idea of stages can not be abandoned on the ground of such criticism, because a modular view is not able to propose a reasonable alternative to structural ideas.

## 4. Stages of mental development: current state

The section is divided into three parts: (a) the problem concerning contradictions within a structural approach to the question of general stages in mental development is delineated, (b) recent solution to the problem, proposed by Lewis (1994) is described, (c) issues that make assumptions proposed by Lewis difficult to sustain, are discussed.

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2 The reports of empirical studies, cited in this article, may originate from paradigmatically different perspectives on the development. Our interpretation may differ from the original interpretation as a result of paradigmatically different perspectives on empirical findings.

*4.1. Tension between general stages and conceptual specificity*

Stage theories have rested on the assumption that the mode of thought characteristic of any particular stage applies for many tasks and problems. However, many authors have found that there is intraindividual and interindividual variability in the levels of mental operations (e.g. Flavell 1982, 1992, Siegler 1989, 1994, Siegler and Crowley 1991, Stehr 1991, Vygotsky and Luria 1930, Wertsch 1990). Such findings seem to contradict the idea of domain-general stages in development (but see Werner 1973). Rather, it is suggested that the development would be conceptualized as a continuous change in specific domains of knowledge (Siegler and Crowley 1991, but see Siegler 1994, Siegler and Crowley 1994 on a more advanced discussion of the problem).

Nevertheless, the idea of general stages and the idea of domain-specific development are not mutually exclusive. Variability and universality may be the characteristics derived from different levels of analysis. When for some human characteristics there is no normal variation at one level of analysis (e.g. having cerebral cortex), then at another level of analysis, all of these species-typical characteristics show variation (Scarr 1992). Scarr's position, advocated also here, is that a good developmental theory must have concepts of both variant and invariant species patterns.

*4.2. Lewis's neo-piagetian theory of self-organizing conceptual structures*

Over the past two decades, neo-Piagetian theorists have attempted to reconcile the incompatibility of stage and specificity characteristics of development. We discuss a theory proposed by Lewis (1994) because it introduces a very important idea of 'soft' constraints on the development. Lewis analyzed neo-Piagetian theories, particularly that by Robbie Case, and indicated some problems related to those theories. He also proposed a reconceptualization of some notions in Case's theory for overcoming the problems inherent to the recent theories of stages.

According to Lewis (1994) the notion of central conceptual structures, proposed by Case, can be reinterpreted so that the contradiction between general and specific characteristics of the development can be resolved. Central conceptual structures are viewed as semantic networks, or systems of nodes and links, which are assumed to represent the child's knowledge about a particular class of problems, corresponding with a particular knowledge domain. Lewis demonstrated that if particular conceptual structures provide a vehicle for identifying and measuring general epistemic advances, or general stages, these conceptual structures must be general too. However, such conceptualization leads to the problem of "circularity", discussed above.

For resolving the problem, Lewis introduced the idea that complex conceptual structures, which achieve global stability in response to interacting constraints, can be described as self-organizing, nonlinear dynamic systems. Theoretically, dynamic systems are systems that are sensitive to their environments, as well as to their own evolving constraints. In the development of dynamic systems the internal coherence and increasing complexity is achieved without internal and external prespecification.

Lewis suggested that central conceptual structures must be idiosyncratic, since they evolve in response to a history of cognitive construals whose individuality is amplified by iterative processes. The idiosyncratic, specific nature of developmental processes is only one side of the same coin. The other side is that individual characteristics and characteristics of the idiosyncratic environment interact with the general *soft* constraints of maturation and culture in guiding developmental outcomes. It means that coherent structures develop without reliance on a prespecified plan or external agent. Rather, global properties emerge from the multiple specific constraint satisfaction. Here every specific constraint is 'soft' in respect to the global properties of the system as a whole. Under the influence of such soft constraints conceptual structures can be configured in a huge variety of ways and still shift in rough synchrony as their elements couple and stabilize at characteristic ages.

### *4.3. Relationships between formal models and concrete phenomena*

Lewis's account is based on the idea that principles of the theory of dynamic systems can be applied to the analysis of mental development. However, there is a problem with such application. On the one hand, it is demonstrated that different classes of formal models can be applied to the study of mental phenomena, including that of cognitive development (e.g. Duke 1994, Hanson and Burr 1990, Plunkett and Sinha 1992, Seidenberg 1994, van der Maas and Molenaar 1992, van Geert 1994).

On the other hand, formal models allow the description of different phenomena by the same models and the same phenomena by different models (e.g. Haberlandt 1990). However, concrete phenomena are absolutely constrained by the starting point of their development. It means that, when more complex structures develop on the basis of less complex structures, then their development is 'topographically' absolutely constrained – not everything can be built from the *specific* collection of elements, which stand at the beginning of the development. Consequently, differentiation between 'soft' and absolute constraints cannot be done at the level of formal modeling alone, but rather has to be retrieved from the analysis of concrete phenomena that are described by formal models. This is because for formal models alone, all constraints are soft, collection of elements in a model is, at least potentially, arbitrary. In the case of concrete systems, on the contrary, the collection of its elements is never totally arbitrary. For this reason formal models alone can not reveal constraints which are *specific* to the phenomenon under study (see also in Lamberts and d'Ydevalle 1990, Plunkett and Sinha 1992, van der Maas and Molenaar 1992, for more information about the constraints of formal models).

Thus, formal models may be very useful for defining general theoretical principles that apply in a variety of domains (Duke 1994, Seidenberg 1994, Valsiner 1994c, van Geert 1994). Yet, formal models must be constrained by the principles which derive from the analysis of concrete phenomena under study. Otherwise it is not possible to differentiate between absolute and soft constraints on the development.

The discussion above has implications in respect of the Lewis (1994) model: When Lewis explained the stages of cognitive development through the interaction between individual, idiosyncratic characteristics, and soft cultural and maturational constraints, his primarily deductive approach does not give us a possibility to differentiate between soft constraints and absolute constraints.

## 5. New definition of a stage of mental development

Here we follow the idea that general stages of mental development can be characterized by a sequence of constraints posed over mental structures. The idea in itself is not new (e.g. Campbell and Bickhard 1992, Case 1985, 1993, Lewis 1994). The main difference relative to other theories lies in the definition of the constraints.

For understanding the following analysis it is necessary to introduce four hierarchic levels of the analysis of mental development. After the description of the levels, a new definition of a stage of mental development is proposed.

### *5.1. Why is the differentiation of levels of analysis necessary?*

We have mentioned already that there is a theoretical trend in psychology that acknowledges the idea that the same phenomenon may seem qualitatively different when analyzed at different levels of generality (Duke 1994, Munro 1992, Scarr 1992, Teitelbaum and Pellis 1992). One way to understand the levels of analysis argument is to refer to different levels of study of tangible, physical reality. According to such argument, it is possible to reduce behavior to physiology, physiology to genetics, genetics to biochemistry, etc. However, we mean another, metatheoretical argument.

We differentiate between four levels of analysis. The differentiation of levels is necessary because structures can be characterized by different types of properties. We assume that each type requires different methods of analysis and conceptualization. It is important that 'topographical' and 'dynamic' characteristics of structures are not in one-to-one correspondence. When 'topographical' factors qualitatively constrain the types of possible processes a structure may support, then there is still a possibility of variation in the processes. This variability is described by 'dynamic' factors. Thus, these factors require different types of analysis.

Next, we assume that dynamic factors interact with topographical factors, i.e. topographical factors may change under the influence of processes, that are described by dynamic factors. Correspondingly, there are different kinds of 'topographical' factors. As changes in topographical factors are induced by dynamic factors that operate within the same topographical factors, different types of topographic factors are internally related. Different levels of topographical factors form 'genetic levels' that are qualitatively different but genetically (i.e. developmentally) related (cf. Werner 1973).

So, there should be a level of analysis that concerns movements from one genetic level to another. As dynamic factors are only partly determined by topographical factors, the movement from one genetic level of topographical factors to the next can never be guaranteed in concrete cases. For this reason we call this level of analysis a 'soft' constraint level.

Finally, we differentiate a 'metatheoretical' level of analysis. This level is a framework that connects other levels. In other words, metatheoretical analysis defines how the levels of analysis are related. All levels are discussed below in more detail.

## *5.2. Levels of analysis*

### *5.2.1. 'Metatheoretical' level of analysis.*

We differentiated between two approaches to the study of mind, 'modular' and 'structural' These approaches make different predictions regarding how to analyze the organization of a mind. In a modular perspective "independent" modules are sought. Correspondingly, such approach may need two levels of analysis, one for identifying 'modules', and the other for characterizing their quantitative growth. Structural approach, on the other hand, is supported on the different kind of analysis. Correspondingly, the levels of analysis in a structural perspective should differ from the levels in a modular perspective.

So, before proposing concrete levels of analysis, it is necessary to define a *metatheoretical* level of analysis. At this level it should be clearly defined which of the approaches, modular or structural, is followed. This is because these approaches need different conceptualizations of the levels of analysis.

The metatheoretical level of analysis alone is certainly insufficient because it operates similarly in physics, biology, and, as we believe, in psychology. Thus, for understanding the meaning of metatheoretical constructs they must be constrained by lower levels of analysis. In this sense the relationships among levels are asymmetric but mutually enriching.

It is assumed here that the development is a structural transformation. It means that we define our metatheoretical level as a theory of structures.

### *5.2.2. 'Topographical' level of analysis.*

This level of analysis defines qualitative constraints on the development of one concrete structure, the structure of mind. It can be assumed that the whole process of mental development is absolutely constrained through a starting point of the development, which is universal for all normal individuals of a species. This is because, according to the principles of a structural theory, nothing develops from nothing, for the development to take place at all, the organism must possess some primary (pre)mental structures from the very beginning of the development. The absolute topographical constraints result from the nature of concrete structures where the possible types of structures are determined by specific sets of elements, which constitute the starting point of the development. For example, a worm can never achieve a human-like mind in any kind of environment due to its species-specific absolute constraints on the development.

We propose that in the case of mental structures the starting point of development should be defined in terms of knowledge structures because knowledge representation (including innate forms of 'knowledge') is a quality that differentiates between biological systems from non-biological systems. Indeed, despite the inter-species differences, there is an invariable property which characterizes all animals. All animals have sense organs (or at least their analogues, receptors). This property is absolutely necessary for the mental development to take place at all. Thus, possession of sensory abilities can be understood as a common 'starting point' to the development of all animals.

From this perspective, development takes place in the direction of the increasing ability to coordinate one's knowledge about the environment (which is built on the basis of sensory perception), with one's actions, for better adaptation to the environment. The more it is possible to represent changes in the environment, the more an organism is able to survive and reproduce itself. Thus, mental development leads to an increasing ability to construct representations of environmental processes and structures.[3] The ways how such a knowledge can be constructed, are absolutely constrained by the starting point, the sensory system.

Further, we propose that the stages of mental development, if they exist, should be defined at this level of analysis. This is because a concept of genetic levels (i.e. stages) of development implies a definition of constraints on systems that characterize qualitative (topographical) limits of all processes that are "in the same stage".

### *5.2.3. 'Soft' constraints level of analysis.*

The third level of analysis would concern how different genetic levels are interconnected developmentally. We call this a 'soft' constraints level of analysis because at this level it would be possible to define general soft constraints of maturation and environment, which are similar to those proposed by Lewis (1994). These constraints are 'soft' because they guarantee only rough synchrony of individual developmental lines in the terms of time (chronological age) or space (environment).

[3] In line with Valsiner (1991) it is assumed here that knowledge, including a scientific knowledge, can only be "constructed" but not "collected".

In terms of analysis it means that at the 'soft' constraint level it is analyzed how development onto higher genetic levels is realized in conditions defined by different maturational and environmental constraints.

*5.2.4. Individual-dynamic level of analysis.*

Mental structures of individuals develop on the basis of individual, idiosyncratic experience. The idiosyncratic nature of individual experiences makes individuals different from one another. There are two interactive sources of such differences, those which are related to differences in environments, and those which are related to differences between individuals themselves. Since these sources of differences are interactive, the same environments may lead to different mental structures in different individuals, and similar individuals may achieve different mental structures in different environments. At this level of analysis, specific outcomes of the development are unpredictable (cf., Valsiner 1992b, 1994a).

Nevertheless, this level of analysis is as important as the higher levels because this level of analysis proposes most stringent criteria for theories formulated at higher levels. We already discussed that, metatheoretically, constraints that are defined at topographical level of analysis must by definition characterize boundaries for all processes of a certain kind of structures. So, only one case of observations where principles defined at the topographical level of analysis are violated may be sufficient for disproving a theory defined at that level.

### *5.3. A definition of a stage of mental development*

Now it is possible to propose a new definition of a stage of mental development. For defining a stage of the development, we rest on the idea of topographical constraints on the processes of a structure: Topographical factors do not determine exactly what kinds of dynamic processes will be supported on the structures. They are characteristics of qualitatively constrained potential behaviors that can be supported on the structure. The potential is not necessarily realized. Correspondingly, *a stage of mental development is a realization of the developmental potential that is absolutely constrained by topographical characteristics of a genetic level of structural development.*

A stage begins with the emergence of a *potential* for the development of qualitatively more complex structures. The potential is created when lower-order structures are differentiated, and unstable so that integration of differentiated elements is possible. In other words, that developmental potential is created when processes, supported by the structures at the level *n*, may become structures of the next stage of development (cf. Munro 1992, and subsection 1.2. A 'structural' view, above).

It is important that, according to a structural perspective, mental development is a "co-construction" of mind in dynamic interaction between the individual and the environment (see 1.2. "A 'structural' view", above). Correspondingly, a stage of mental development is not an individual property that can be found in the individual where it is usually searched for. Rather, a stage is a property which emerges in the interaction between the environment and the individual.

Such conceptualization provides a way for understanding relationships between universal and specific characteristics of mental structures. If a stage is only the realization of a potential defined by specific level of structural development, then large differences between and within individuals may emerge because the potential can be realized only in the interaction with the environment. And such interactions are idiosyncratic due to idiosyncracies in experienced environments and individual properties.

We describe a purely hypothetical example for clarifying the issue. We can imagine two children, one living in a hospital and the other living in a forest. If to suppose that these hypothetical children are able to develop only visual representations, then it can be assumed that visual representations of these children are entirely different. For one child visual representations contain information only about a hospital and for the other child information only about a forest. Nevertheless, both collections of representations are absolutely constrained, they are only and only visual. The absolute topographical constraint the children share allows to build visual representations characteristic of the other child under the influence of the corresponding environment.

Thus, there can be large inter-individual differences between organisms under universal topographical constraints. If the structure of mind is horizontally differentiated and vertically hierarchical (orthogenetic principle, Werner 1957, 1973), intra-individual differences may also occur. For example, if one of these hypothetical children has representations for visual and olfactory characteristics of objects, there are two sources for intra-individual differences, 'horizontal' and 'vertical'. In the horizontal dimension the visual and olfactory representations may concern two categories of objects. There are objects represented as odors, and objects represented as visual images. In addition, in the vertical dimension there are objects represented both visually and olfactorily. Thus, in this hypothetical case, intra-individual differences may concern three categories of objects: visual but odorless, nonvisual but with an odor, and both visual and with an odor. Again, each of these groups of objects is processed in the limits posed by absolute constraints (the representations are only and only visual and/or olfactory), but in the interaction with the environment, a variability in the structure of representations can develop.

In sum, a development of mental structures can be described by the highest *possible* genetic level of processes an individual is able to achieve in any specific domain of knowledge. For an individual, this highest possible level is determined by three types of constraints – individual-dynamic (idiosyncratic nature of individual experience), soft (culture and maturation), and topographical. A stage of mental development is a realization of the potential under the three types of constraints.

## 6. Stages of ontogenetic development. first steps

So far, the analysis has revealed that there is no sufficient ground for rejecting the idea of general, universal stages in mental development. As yet, however, there is also no reason to accept the idea. In this section a rationale is given for a need to differentiate universal stages of the development. The differentiation is achieved at the topographical level of analysis.

### *6.1. Topographical constraints on mental development. The first three stages.*

#### *6.1.1. Constraints at the first stage.*

As the development of concrete systems is absolutely constrained by the starting point of the development, the first question to be answered is where begins the development of mental structures? It was already proposed that such development begins with the acquisition of sensory abilities. The reason behind the proposition lies in the assumption that sense organs developed for the adaptation to the environment (Leont'ev 1981, Vavilov 1950).

Following this idea we suggest that first sensory abilities are constrained to the ability to grasp only *independent individual sensory attributes* (e.g. individual odors in an olfactory system, or colors, orientations, movements, in a visual system). The reason for this suggestion lies in two assumptions. First, differentiation and hierarchic integration is a result of development. Therefore, when (pre)mental structures differentiate from lower-order structures, a degree of differentiation should be low. And, correspondingly, only limited aspects of the environment can be represented internally. Second, if only limited aspects of an environment can be represented, then the most regular kind of environmental characteristics should be represented for making a system as stable as possible. In our opinion solitary sensory attributes are the most regular kind of possible sensations of environments where organisms live. All combinations of sensory attributes, however, are potentially irregular. Therefore, under pressure of relatively low level of differentiation, it should be nonadaptive to have regular representations of potentially irregular phenomena. In this case information about relationships between solitary sensory attributes should be acquired individually, in the process of the interaction with the environment.

For defining the starting point of mental development it is also necessary to understand what kinds of behaviors can be supported on the representations of solitary sensory attributes. If an organism is able to perceive only solitary sensory attributes, without an ability to connect them, every attribute can have only one "meaning" for an organism. The "meaning" of such attributes does not change in different contexts of other solitary attributes. In addition, to be "meaningful" to the organism at all, there must be a correspondence between sensations and actions (Leont'ev 1981). Otherwise the sensation cannot be adaptive.

If representations contain information about units with one "meaning", the behavior can only be in one-to-one correspondence with such units. Such behaviors are nothing but *reflexes*, where sensory attributes and corresponding behaviors are not differentiated but constitute a unitary whole. Correspondingly, at this level, processes and structures are not differentiated.

It should be noted that *quantitative* growth is possible within the same topographical constraint of unity of sensory and motor processes. For example, it would be possible to represent two or more sensory attributes together, as in a case of innate multimodal sensation. However, an organism at this level of development should be unable to learn that the same group of sensory attributes may have different meanings in different contexts, i.e. the same "frozen" group of sensory attributes remains to be connected with only one type of actions (or, analogously, "frozen" action sequences).

*6.1.2. Constraints at the second stage.*

Would an organism be able to represent all aspects of an environment by solitary sensory attributes, or their "frozen" groups, there would be no need for the development. However, it is not possible because sensory systems are constrained and may transform only limited number of qualities of an environment into internal representations. For example, we can only see within a limited band of light frequencies reflecting from objects which are not too small, we hear only limited frequencies of sound-waves, etc.

According to the orthogenetic principle (Werner 1957, 1973), for the next development the differentiation of lower level structures must take place. Otherwise the development of a new level of integration would not be possible. In our case the only structure which can differentiate is the unitary whole of the direct correspondence between individual sensory attributes and reflex behaviors. Through the differentiation of this whole it becomes possible to support new kind of processes where relatively regular relationships between sensory attributes are detected and represented. It is noteworthy that, as the first step of the development allowed only the representation of solitary sensory attributes, the following development is constrained. From such attributes it is possible to build only higher level structures, which represent these attributes *and* relationships between these attributes.

A potential to represent relationships between attributes requires a new kind of behaviors, because now the same sensory attributes may acquire different meanings when they appear in different contexts. It follows that behaviors, supported by structures of the second stage of development, are *conditioned reflexes*. This is because at this stage an organism has differentiated only reflex actions, and sensory attributes which can be combined in novel ways. Only conditioned reflexes can be built from such elements.

Conditioned reflexes are *learned* behaviors, where the already existing behavioral patterns are connected with new kinds of stimuli. Other kinds of relationships between representations and behaviors should be, according to a structural view, logically impossible (see also studies by Ivan Pavlov, e.g. 1951, whose results indirectly support such a conclusion). The ability to learn individually, in turn, is a more adaptive way to cope with an environment than a purely reflex behavior. Here lies a force which conditions the development.

*6.1.3. Constraints at the third stage.*

At the third stage of development, again, the potential of the lower level is realized. When the emergence of relationships between sensory attributes was a process at the second stage of development, it is transformed into a structure of the third stage. For this, a differentiation of some lower level phenomena is necessary. At the third stage, we suggest, a specific kind of relationship between sensory attributes differentiates. These are relationships between sensory attributes of *objects*, because such relationships are more regular than other possible relationships between sensory attributes an organism perceives. Thus, it becomes possible to represent objects in mental structures.[4]

This change of the process into structure allows to support new kinds of processes which detect specific relationships between objects. In this way it becomes possible to represent "situations", i.e. objects in their specific relationships with other objects. The process by which such representations are built is analogous to "perceptual analysis" (Mandler 1988, 1992). Perceptual analysis is a process in which a given perceptual array is attentively analyzed, and a new kind of information about the meaning of a piece of perceptual information is recoded into a non-perceptual form.

So, representations of "objects" are representations of only such relationships between individual sensory attributes, which have a potential to obtain different meanings in a context of other object representations. It means that the functions of objects are represented. Therefore, sensory and functional properties of objects are in hierarchical relationships (the latter develops on the basis of the former), and, correspondingly, it is necessary to differentiate between relationships of sensory attributes and functional relationships between objects (see also Gelman and Medin 1993, Mandler 1988, 1992, for an analogous differentiation of conceptual and perceptual information).

Structures at this stage of development require also a new kind of behavior, because now the same "objects" (specific relationships between individual sensory attributes) may acquire different meanings in the context of different objects. According to structural principles, such new behaviors can be produced only with the help of differentiated elements of existing structures – representations of objects with their specific relationships and behaviors which are not in one-to-one

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[4] It is noteworthy that Marr's (1982) model of object perception, based on computational logic, is very similar to our model. The primal sketch, $2^1/_2$-dimensional sketch, and a 3-dimensional model, which are in hierarchical relationships according to Marr, are analogous to the representation of individual sensory attributes, relationships between attributes, and representations of objects, respectively. Such parallel supports the idea that the proposed invariant sequence of stages is logical.

correspondence with solitary sensory attributes, but are learned. Behaviors of this type can be called *"intellectual operations"* (cf. Vygotsky and Luria 1930). In such behaviors internal *plans* are created before the act of behavior is released. These internal plans are based on the information about the relationships between objects. The plans contain information about how an object should be influenced by another object to achieve a goal.

In summary, the first three stages of mental development can be characterized in the dimension of representations by an ability to represent solitary sensory attributes, relations between sensory attributes, and objects, respectively, and in the dimension of behaviors by an ability to release reflexes, conditioned reflexes, and internally constructed plans, respectively. These characteristics of stages ('genetic levels', sensu Werner 1973) are definitions of topographical factors. The 'individual-dynamic' realization of topographically constrained potential under soft environmental and maturational constraints constitutes a stage of development.

### *6.2. Analysis of empirical data.*

Description of stages, we proposed, is in many respects similar to other stage theories. For example, according to Piaget's theory (see Flavell 1963, for a review) the first, sensorimotor, stage from birth to approximately age two forms a qualitatively discrete period of development which can be divided into six substages. During this period an infant moves from a neonatal, reflex level to a relatively coherent organization of sensory-motor actions vis-a-vis his/her immediate environment. A description of ontogenetic development, analogous to the present one, was also proposed by Vygotsky. He suggested that a child is born with an ability for only reflex behavior, after that, from the age of about two months conditioned reflexes develop (1935). Next, from the age of about six months a child begins to master abilities related to actions with objects (1935, 1984).

These and other stage theories, however, depart crucially from the present account. Even when the idea of differentiation and integration – the orthogenetic principle – is taken seriously (e.g. Robbie Case's theory), as far as we know there has been no stage theories where levels of analysis are clearly defined and superficial contradictions with 'continuous change' and 'quantitative change' views are solved. We suggest that such metatheoretical differentiation of levels of analysis is necessary for understanding the mechanisms of development. It does not mean that we oppose our theory to other theories of development. On the contrary, we believe that as the phenomenon of mental development that different theories try to conceptualize is the same for all of us, and all theories are more or less in accordance with empirical data, we should search for a common framework to understand relationships between different theories. Unfortunately, space limitations do not allow to analyze similarities and differences of all other stage theories with our approach more deeply.

Now we turn to the analysis of empirical data. We suggest that if topographical constraints on the development are in hierarchical relationships, then in the development of every specific process the postulated lower level must precede the development of the next, higher level in the invariant sequence. Thus, it should be possible to falsify our model by findings that representations of objects and/or relationships between objects, and corresponding types of behaviors, develop either earlier or simultaneously with the development of unconditioned reflexes. It is demonstrated below that there seems to be no evidence which contradicts our predictions.[5] On the contrary, empirical data fit well with the theoretical model that was described above.

*6.2.1. First stage. Reflexes and individual sensory attributes.*

At this stage sensations and reactions form a unitary whole. As such wholes are based on innate mechanisms, they should also be in close (but not in one-to-one, cf. Gottlieb 1991, Thelen 1995) correspondence with the maturation of specific structures of the nervous system (cf. Medicus 1992, Werner 1973). For this reason the following discussion of empirical evidence concerns also maturational changes of the nervous system of human embryos.

The nervous system starts developing approximately 18 days after fertilization (Majovski 1989). All primary efferent nuclei of the human brain are laid down at their definite sites before the eighth week of gestation. Functional reflex connections are made after 8 weeks of gestation. However, there is no cerebral cortex at this age (Windle 1971, see also Brown 1990, on the development of fetal reflex swallowing). Peripheral and subcortical auditory (Schwartz et al. 1989), visual (Snyder et al. 1990), and proprioceptive (Tranier et al. 1989) systems are functional from the sixth or seventh month of postconceptual age although the central, cortical structures subserving the same functions, are still immature. Thus, cerebral cortex, which is necessary for the achievement of conditioned reflexes (Pavlov 1951), is immature at this time (see also Dambska and Laure-Kamionowska 1990, Gottlieb 1971, Hood and Atkinson 1990). In addition, corticospinal and corticobulbar efferent tracts, which subserve the learning of new movements in adults (Kennedy 1990) do not support the learning functions in newborns (Sarnat 1989).

Thus, data which characterize the development of the nervous system, indicate that structures which subserve learning of new movements and new stimulus-reaction relationships become functional after the structures which subserve reflexes. There is also evidence which demonstrates that within first weeks after birth children react mainly on individual perceptual attributes. For example, it has been demonstrated that newborns younger than 24 hours response selectively to the mother's and father's spontaneous speech (Ockleford et al. 1988). However, such specific reactions are responses to one sensory attribute of speech, that of intonation, even in one-month-old infants (Mehler et al. 1978).

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5 Although the absence of the evidence is not the evidence of the absence, we follow the idea, recognized long ago in physics, that every model is good until the evidence is found, that does not fit into it (Heisenberg 1989).

*6.2.2. Second stage. Conditioned reflexes and relationships between sensory attributes.*

There are several changes in the behavioral and representational abilities of infants after birth. First, coordination between reflexes (reflex modification) develops (Anday et al. 1989, Weissman et al. 1989).

Second, conditioned reflexes start to develop from birth (Olson and Sherman 1983, Rovee-Collier 1987), although it is difficult to demonstrate conditioning before 3 weeks of age (Olson and Sherman 1983, Sameroff and Cavanagh 1979) or even later (Pomerleau et al. 1992).

Third, reactions start to differentiate from stimuli. The differentiation is reflected in a similar reaction of novelty to very different stimuli. In studies of young infants the reaction is called "dishabituation" (see references below).

Fourth, correlations between sensory attributes are detected. For example, young infants can differentiate syllables (Eimas and Miller 1992, Novak et al. 1989). This differentiation is, as our model would predict, not a phonetic but an acoustic process (Aslin 1989, Nozza et al. 1990). There is also evidence that 5-month-old infants are able to detect correlations between shape and color attributes (Catherwood 1994). However, it is not an easy task to detect, for example, intermodal (e.g. auditory-visual) correlations between sensory attributes (Lewkowicz 1992), or relationships of attributes of complex stimuli (Nelson and Collins 1992) even at the age of eight months. It should be mentioned that there are also suggestions that 3-month-old children are able to represent objects (e.g. Quinn et al. 1993). However, as the term "object" has a specific meaning in our theory, the discrepancy is only superficial (see below).

Finally, representations of object categories start to differentiate. This differentiation begins around the age of three months when children become able to differentiate object boundaries and realize that objects continue to exist when hidden (e.g. Baillargeon 1993, Baillargeon and de Vos 1991, Spelke et al. 1992). It is also demonstrated that 4-month-old children "understand" that objects move continuously (Spelke et al. 1995). Such findings seem to contradict the idea, proposed by Piaget, that young infants do not have a concept of object permanence. Empirical findings of young infant's abilities have been interpreted either as reflecting a presence of some unchanging "core" of knowledge about objects (by Elizabeth Spelke and her colleagues) or as reflecting the presence of some highly-constrained mechanisms that guide the development of infants' reasoning about objects (by Renee Baillargeon).

In principle, both these ideas can be accommodated into the present model with one modification. The modification is that the described findings demonstrate not the presence of the concept of *objects* (in our specific sense), but simply a specific case of an ability to detect and process *relationships between sensory attributes*. For the present model the difference is substantial – if young infants have concepts of objects, then, according to the principle of differentiation, different objects should have different meanings – they should have "functions".

Indeed, cited findings only demonstrate that for young infants all "objects" have boundaries, and are continuous and solid. Such characteristics are similar to all objects, and, correspondingly, do not differentiate them. Our suggestion that objects are not differentiated from other kinds of relationships between sensory attributes can be supported by findings of Spelke et al. (1993). They demonstrated that Gestalt relations of sensory attributes have no effect on the perception of relations of color and texture attributes in three-month-old infants. Thus, objects are not qualitatively distinct wholes for very young infants.

Here the question emerges – On the basis of what kind of information can such properties of objects be processed? We suggest that decisions about "object" boundaries and continuity can be based on the processing of one individual sensory attribute, that of form (shape). There is evidence that the processing of a visual form is segregated at early (subcortical) levels of visual processing (cf. Kandel 1991, Livingstone and Hubel 1987, Maunsell and Newsome 1987, see also Marr 1982). Thus, for three-month-old infants it is only necessary to detect regular relationships between shapes to "understand" general characteristics of "objects". In this case, the innate "core" of object knowledge (Spelke's approach) is an ability to detect one individual sensory attribute, shape. At the same time, as processes and structures are dialectically related, the number of possible mechanisms of processing shape information is also highly constrained (Baillargeon's approach).

*6.2.3. Third stage. Objects and intellectual operations.*

As it was discussed in the previous section, objects start to differentiate from other relationships between sensory attributes around the age of three months. It is interesting that the detection of Gestalt relations between sensory attributes that appears at the age of about five months (Spelke et al. 1993, Younger and Gotlieb 1988), develops chronologically in parallel with stereopsis (Teller 1990), and with the ability to detect relationships between different spatial arrangements of forms (Lecuyer and Poirier 1994) or individual sensory attributes (Roder, Bates, Crowell, Schilling, and Bushnell 1992).[6] Since specific spatial relations between objects are an important source of information for representing functions of objects, the chronological parallel would be lawful. There is also evidence that there are general changes between 7 and 13 months in the way infants process categorical information (Younger 1990, 1993, Younger and Cohen 1986). According to the present account such changes in perception reflect the differentiation of categories of objects.

The studies with habituation procedures have demonstrated that very young infants are able to differentiate between object boundaries and realize that objects

[6] Such detection must also be supported by a system which analyzes individual sensory attributes. In this case the decision can be made on the basis of the "where" system of the vision, which detects spatial relationships between changes of regularities in the environment. This system is differentiated early in the visual structure (cf. Kiorpes and Movshon 1989, van Essen 1979, Weiskrantz 1989).

continue exist when hidden (see above). Such findings led to the understanding that young infants might perform poorly in search tasks, not because of incorrect beliefs about occlusion events, but because of difficulties associated with the planning of means-end search sequences. This idea fits well with the present model, which also offers an explanation *why* infants have difficulties in planning. For planning such goal-directed behaviors it is necessary to represent information about functional properties of objects, i.e. to represent "objects" in our specific sense. Thus, it can be predicted that changes in representations of categories in the second half of the first year, discussed above, reflect the development of representations of objects. In this case the development of infants' ability to plan goal-directed behaviors with objects should parallel the development in perceptual abilities. Empirical findings are in agreement with this prediction.

For example, between 7 and 12 months, there is a parallel improvement in "A not B" hiding task and Delayed Response task (Diamond and Doar 1989), and the ability to retrieve an object from a plexiglass box (Bell and Fox 1992). Quantitatively more complex abilities such as logical search, performance in invisible displacement tasks, and means-ends understanding with immediate "insight" (characteristic, which differentiates conditioned reflex behaviors from intellectual operations), develop between 9 and 18 months (Gopnik and Meltzoff 1984, 1987, 1992, Haake and Somerville 1985). In addition, by late in the first year of life, children are able to accurately remember specific sequences of actions with objects and organize event sequences into wholes (Bauer and Mandler 1992). For such behaviors, again, it is necessary to detect specific relationships between objects.

In sum, empirical evidence is in agreement with the idea that the development proceeds through an invariant sequence of stages that were identified theoretically, "independently" from specific behaviors of children.

### *6.3. A question of additional stages*

We described the first three putative stages of mental development. We believe that similar analysis may lead to discovery of additional stages as predicts, for example, Vygotsky (1982, Vygotsky and Luria 1994). According to him, child development would follow the development of word meaning after the psychic processes become semiotically mediated. Vygotsky suggested that semiotic mediation would be a mechanism for organizing information differently from the thinking on the basis of sensory analogy. It is demonstrated in semiotics that interchange of information between differently built semiotic (information processing) mechanisms is a law which characterizes all types of constructions with an ability to think (e.g., Lotman 1981). According to Lotman's view, for generating novel information, at least two differently organized mechanisms of information processing must be interacting, the new information emerges in the "translation" process of information from one system to another. When there is no contact between semiotic mechanisms, interchange of information is impossible and no novelty can be produced. This principle operates both at the level of an individual organism (Lotman 1983) and at the level of relationships between cultures (Lotman 1992). Therefore, the development of semiotic mediation of psychic operations (i.e. an acquisition of the qualitatively novel way for organizing information) would be a good candidate for looking for next stages of mental development.

## 7. Conclusions. Mental development and different levels of analysis

The primary objective of this article is to suggest that the concept of universal, invariant stages of mental development is not only useful, but necessary for understanding mental development. Nevertheless, we do not suggest that a stage theory is sufficient for that purpose. Rather, we propose that it would be inappropriate to pose a question – Quantitative change *or* continuous change *or* universal stages? – as mutually exclusive possibilities. Our approach postulates that none of the approaches to the study of mental development is inappropriate or irrelevant. Instead, the question should be how the different ways of conceptualization may enrich one another.

For understanding relationships among different approaches to mental development, four complementary levels of scientific analysis were proposed. There is a principle from Chaos theory, according to which, depending upon the scale at which behaviors are examined, different methods of analysis and conceptualization are needed (Duke 1994). Following that principle, we propose that in addition to the differentiation of levels of analysis, it should be necessary to define the objectives and methods of the levels. The levels of analysis are briefly outlined as follows.

First, the objective of the 'metatheoretical' level of analysis would be the definition of abstract rules, which operate at lower levels of analysis. In our opinion a theory of structures would be the first choice for that level of analysis. It is important to realize that a metatheoretical level is insufficient for understanding the development because at this level it is not possible to differentiate between absolute and soft constraints on the development. For overcoming the obstacle lower levels of analysis are needed.

Next, the objective of the 'topographical' level of analysis should be the definition of universal constraints on the development of mind. Methodologically, a 'modular' approach should fit well for such analysis. This is because this approach inherently looks for universal, "independent" determinants of behavior. As was discussed above, topographical constraints on the development should be the same for all behaviors that are at the same stage. In this way, the characteristic is "independent" of all specific behaviors, although for revealing it, *some* behaviors must be manifested.

This level allows also a *quantitative* description of the development, similar to that proposed by Flavell (1985, 1992), as it is possible, for example, to study how many behaviors have realized the potential of a stage, and how "big" is a knowledge underlying the behaviors. Nevertheless, a 'modular' approach alone would remain adevelopmental because topographical factors change in the course of development. Topographical level of analysis does not study dynamical factors, i.e. change mechanisms. For that individual developmental pathways should be studied. So, results of studies that follow a 'modular' methodology acquire developmental meaning only in a context of other levels of analysis.

Third, the objective of the next level of analysis should be the definition of "soft" (environmental and maturational) constraints on the development (cf. Lewis 1994). At this level mechanisms of transition from one topographical genetic level to another are defined. Such transitions depend on the realization of a *potential* for mental development that is constrained by topographical factors. As this realization, in turn, depends on several concrete organismic and environmental constraints, the transition from one genetic level to another can never be predicted absolutely. Correspodingly, idiosyncratic characteristics of such constraints make them "soft", i.e. they predict changes only probabilistically but do not determine them. Methodologically, such analysis would require an interactive use of microgenetic (cf. Siegler and Crowley 1991, Siegler and Engle 1994) and 'modular' research methods. From the perspective of this level, mental development would seem as a movement over general stages in the invariant sequence.

Finally, the 'dynamic-individual' level of analysis should be directed at the study of individual, idiosyncratic and unpredictable pathways of the development. Methodologically, microgenetic research strategies would be appropriate here. From the perspective of this level, the development would be best characterized as a continuous change. As in the case of higher levels of analysis, this level alone is also not sufficient for understanding mental development (cf. Kuhn 1995).

In sum, it can be said that there seems to be no reason for abandoning some approaches from the study of mental development. Instead, the analysis revealed four increasingly concrete levels of analysis – 'metatheoretical', definition of 'topographical' constraints on mental development, the definition of 'soft' constraints on the development, and a study of individual developmental pathways. Each of these levels has its own objectives and methods, and, correspondingly, what is irrelevant at one level of analysis (e.g. the idea of general stages), is relevant at the other. We hope that such search for principles which connect different approaches, enriches our current knowledge about mental development.

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