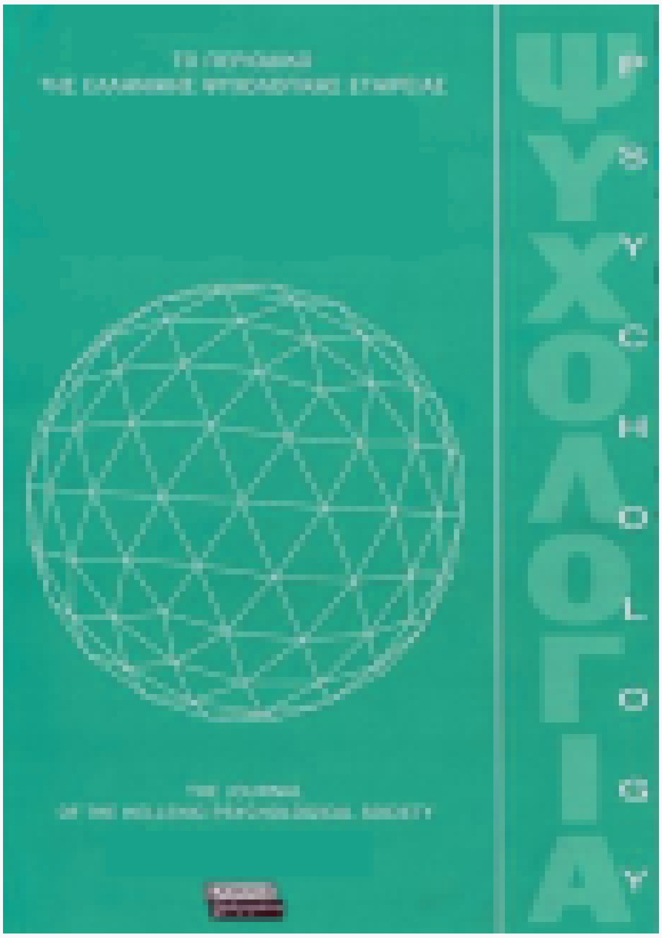
Psychology: the Journal of the Hellenic Psychological Society

Vol 4, No 3 (1997)



Why and how does the mind change? Towards a developmental theory of cognitive change

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doi: [10.12681/psy_hps.24222](https://doi.org/10.12681/psy_hps.24222)

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ABSTRACT This paper presents a theory of cognitive change. The theory assumes that the fundamental causes of cognitive change reside in the architecture of mind. Thus, the architecture of mind as specified by the theory is described first. It is argued that the mind is a three-level edifice. That is, it involves a processing system which constrains what can be processed at different ages, a set of environment-oriented systems specializing on the processing of different types of relations in the environment, and a self-oriented system that governs self-awareness and self-control. The paper then specifies the types of change that may occur within and across levels and a series of general and more specific mechanisms that bring the changes about. Finally, a general model of the nature of cognitive development is offered.

Key words: Architecture of mind, mechanism of change, specialized capacity spheres

Sherlock Holmes: But there was the curious incidence of the dog in the nighttime.
Watson: The dog did nothing in the nighttime
Sherlock Holmes: That was the curious incidence.

By definition, developmental psychology is the science of change. However, it is recognised nowdays (e.g., Demetriou, 1993; Siegler, 1995) that despite its definitional objective, developmental psychology is still impressively poor in capturing, modeling, and explaining change. Although we do have a rather accurate knowledge about the global timing of developmental changes in various dimensions of behaviour and experience, such as cognition and thinking, emotions, social interactions, and language, we still do not know very well what is really changing and what remains invariant in each of these realms, we are very hesitant to name the causes that produce the changes, and we are usually blatantly ignorant of the mechanisms that bring the changes about. Even worse, we are still at the primitive level of arguing with each other about the nature of developmental change as such. That is, up to the present, the field is still divided between the camp of those who believe that change is basically stagelike and discontinuous (e.g., Case, 1992; van Geert, 1994) and those who believe that development is smooth and continuous (e.g., Siegler, 1995). Thus, I hope that you have already figured out who is the dog in the conversation above. Evidently, it is developmental psychology and the curious incidence is its failure to meet its definitional purpose and provide a satisfactory depiction of change. My aim in this paper is to propose a general framework for specifying and modeling change in the development of the human mind. This framework will be based

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primarily on recent research and theorising on cognitive development. It needs to be noted, however, that this framework intends to be applicable to a wider range of phenomena, such as those concerned with moral and social development.

The minimum mental architecture for the development of mind

There is no doubt that Piaget has been the giant of our field. Like many giants in science, he has imposed his misconceptions on the field for about half a century and I think that we still need strong effort to emancipate ourselves from these misconceptions and go forward. Specifically, in my opinion, Piaget misrepresented change in a crucial respect. That is, Piaget (1975) claimed that only structure is changing in human development, whereas the basic mechanisms of development remain invariant throughout the human life. The reader is reminded here that, according to his theory, the same equilibration process, which is driven by the functions of accommodation and assimilation, brings about changes in the coordination of actual or mental operations. These changes yield the structures of the whole which characterise Piaget's well known stages of cognitive development. I will argue below that there may indeed be changes in the structure of psychological processes or characteristics and that there are developmental mechanisms which remain invariant. At the same time, however, I will also argue that, on the one hand, there also are aspects of structure which do not change with development. In fact, the argument will be put forward that a stable mental architeture is a necessary precondition of developmental change and that because of the invariance of this architecture it functions as a source of change. On the other hand, I will also argue that development brings about changes in the mechanisms of change themselves. These changes in the mechanisms of change explain how mind is raised to ever higher levels of functioning.

The kinds of change that any system can undergo are constrained by its structure and the functions that this structure was designed to serve. Thus, if we are to understand the development of the human mind we would have to specify its minimum architecture and its primary functions which define the dimensions along which the mind develops, the fundamental causes which fuel its development, and the basic mechanisms that are responsible for the implementation of change. Mind is a thinking machine which evolved so as to be able to understand states and change in the world, itself included. Thus, its architecture has to involve both world-directed and self-directed «organs» and ensuing functions. In the pages below, we will summarise a theory about the architecture of mind that directly deals with these issues and tries to explore its implications for developmental change. This is the theory which I proposed with my colleagues. In its current formulation, the theory is summarized in Demetriou (1993, 1996, 1997; Δημητρίου, 1993) and it is empirically substantiated in a number of studies which dealt with various aspects of the theory (e.g., Demetriou, Efklides, & Platsidou, 1993; Demetriou, Efklides, Papadaki, Papantoniou, & Economou, 1993; Demetriou, Kazi, Platsidou, Sirmali, & Kiosseoglou, submitted; Demetriou, Pachaury, Metallidou, & Kazis, 1996; Πλατσίδου & Δημητρίου, 1995). The substatiation of the theory on the basis of logic is currently under way (Kargopoulos & Demetriou, in press). At the same time, however, frequent reference will be made to the work of other scholars, since this theory was developed as framework for the unification of cognitive developmental theories.

According to this theory, the basic architecture of the human mind is biologically given and it remains invariant throughout life. Specifically, the theory assumes that the human mind includes two basic hierarchical levels of knowing. The first of these involves environment-related systems, the second involves system-related constructs. At the intersection of these two levels there also seems to be a functional system that defines the activation and the interaction between the two knowing levels. This architecture will be analysed below. However, it needs to be noted here that each of the levels may itself be hierarchically organised. For the present purposes, analysis at this refined level is not needed.

Environment affiliated systems

The first of the two knowing levels involves structures addressed to the environment. Thus, the input to the first level is information coming from the environment and its output are actions, overt or covert, directed to the environment. Empirical research in our laboratory led to the identification of a handful of such structures: categorical, quantitative, causal, spatial, propositional, and social thought (Demetriou & Efklides, 1985, 1989; Demetriou, Kazi, Platsidou, Sirmali, & Kiosseoglou, submitted; Shayer, Demetriou, & Prevez, 1989). Music and drawing, which are now under study in our laboratory, may also be added to the list.

It is assumed that the development and functioning of these structures in both phylogenetic and ontogenetic time is governed by the following three principles. *The principle of domain specificity* states that, for reasons of economy and efficiency, mental processes which are concerned with the same type of relations in the environment tend to be integrated into a thought system which specialises in the representation and processing of these relations. Therefore, different types of relations in the environment result in the construction of different thought systems. These systems are called *Specialised Capacity Spheres* (SCSs)[1]. *The principle of formal-procedural specificity* states that the mental acts and operations characteristic of each SCS bear on common procedural, computational, and formal properties which preserve the domain's structural and dynamic characteristics. The principle of symbolic bias states that each SCS is biased toward those symbolic systems or subsystems which are more conducive than others to the representation of its own properties and relations and to the efficient application of its own operating processes on the elements of the reality domain concerned. In other words, SCSs are considered to be fields of thought that preserve the organisational and dynamic peculiarities of the different fields of reality which made their evolution necessary. As such, each of these systems is a dynamic, multilayered and multidimensional entity that involves three main types of elements or components.

First, each SCS involves ever present kernel elements or core operators that match the defining elements and relations of an SCS's field. For instance, depth perception, subitization, and the perception of physical transmission of movement between objects which are in visible contact with each other, such as a mother and a baby carriage, may be kernel elements of the spatial, the quantitative, and the causal SCS, respectively, at the level of perception. Also, the various SCSs involve core operators at the level of action itself. We propose that the kernel elements

1. At the begining the term «capacity spheres» was used to denote systems of thought which were regarded to be functionally and developmental autonomous of each other (Demetriou & Efklides, 1981, 1987). The intention in using this term was to convey the assumption that these systems may be dimensions of more or less stable individual differences Subsequently, and after long discussions with Robbie Case about the nature of domain-specific structures in thought, we shifted to the term «specialized structural systems» (Demetriou et al, 1993) to denote the same constructs. The aim was twofold. That is, first, to differentiate the environment-oriented domains of thought from processing capacity itself and, second, to convey the assumption, whtich then tended to win, that these systems are environmentally and culturally determined. Now we decided to merge the two terms into a hybrid one: «specialized capacity spheres». This term denotes our present convinction that there is something hardwired in these systems which may coexist with other environmentally and culturally determined constituents. Hardwiring here does not necessarily imply innateness but some kind of shaping of different neural circuits as a result of the interaction with different aspects of the environment.

of each SCS are biologically primary, perceptually engrafted, informationally encapsulated, and present at birth or directly derived from maturational changes early in life.

Second, the systems also involve rules, processing skills, and operations that evolve as a result of the application of the core operators on the environment over time. In fact, we have shown empirically that each SCS is a complex network of component processes and operations which complement each other in the representation and processing of the different aspects of the reality domain to which each SCS is affiliated. For instance, depth recognition in pictures, strategies for effecting mental rotations, and map-reading strategies may be taken as examples of component processes involved in the spatial-imaginal SCS. Arithmetic operations, proportionality, and algebraic reasoning may be taken as examples of the quantitative-relational SCS. Combinatorial reasoning, hypothesis formation, and experimentation may be considered as examples of the causal-experimental SCS (Demetriou et al., 1993; Demetriou, Pachaury, Metallidou, & Kazi, 1996; Demetriou, Efklides, Papadaki, Papantoniou, & Economou, 1993).

Finally, each of the SCSs involves products of the past operation of the core elements, the rules, the processing skills involved in it. These products are conceptions and beliefs about the field of reality each of the SCSs is affiliated to and they constitute the person's knowledge base about this field. Research and theorizing on the so called foundational theories that persons hold for the physical, the biological, and the social world (Wellman & Gelman, 1992) and about conceptual change with regard to these conceptual domains (Carey, 1985) is related more to this level of the organization of each SCS than to the two lower levels described above. That is, in the context of the present theory, foundational theories and ensuing changes are to be regarded as the result of the ongoing application of the various SCSs on the different aspects of the world which generates information about the world which is stored for future use.

Clearly, operations, rules, strategies, and theories of the two higher levels of an SCSs architecture are mental constructions and they, therefore, are biologically secondary to the kernel elements discussed above. Thus, they can be acquired as a result of development at one or the other age. By implication, they are to be considered informationally penetrable (Fodor, 1983).

The hypercognitive system

The second knowing level involves the hypercognitive system. The input to this system is information coming from the first level (sensations, feelings, and conceptions caused by mental activity). Its output are thoughts and feelings which aim to represent and control the functioning of the first level. Thus, the hypercognitive system involves self-awareness and self-regulation knowledge and strategies and is regarded to be the interface between (a) cognition as a whole and reality, (b) any of the SCSs or any other cognitive functions, and (c) the processing system to be described below and the SCSs. To be able to function in this capacity, this system involves three kinds of structures.

a) *A model of the cognitive system.* This model involves knowledge and beliefs that the persons have about the structural and dynamic characteristics of their own cognitive system. For example, this model recognises that there are different cognitive functions, like perception, attention, memory, etc., and different cognitive structures, like the SCSs described above. This model also recognises that different tasks, like a mathematical problem or a map-reading problem, require different kinds of abilities to be efficiently processed, for example addition as contrasted to mental rotation. Recent research on children's knowledge about the child's theory of mind (e.g., Wellman, 1990), thinking (e.g., Flavell, Green, & Flavell, 1995), and other cognitive functions, such as attention and memory (Demetriou et al. ,1993, Study 3) are concerned with this aspect of long-term hypercognition.

b) *A model of intelligence.* This model involves knowledge and beliefs about the nature and the functions of intelligence. Therefore, this model involves representations of the components of intelligence (e.g., people must learn quickly, they must speak fluently and accurately, they must be socially flexible and considerate, they must control their behaviour, etc.) and of the conditions under which the use of each of these components is more appropriate. In other words, this model specifies how the individuals must use their mind in order to achieve their own personal goals without coming into conflict with the social or cultural group in which they belong. Research on implicit theories of intelligence (Sternberg, Conway, Ketron, Bernstein, 1981) sheds light on this aspect of long-term hypercognition.

c) *The cognitive self-image.* The cognitive self-image seems to be at the intersection of the two kinds of models described above. That is, it involves the representations that the individuals have about themselves as intelligent cognitive systems. Thus, this model involves answers to questions like the following: How flexible or intelligent or wise am I? Which kinds of problems am I good at solving and which ones am I not so good at solving? How efficient am I in using different cognitive functions like memory, imagery, problem solving, etc.? In other words, the cognitive self-image involves all descriptions, implicit or explicit, that individuals make of themselves in regard to different mental functions, abilities, strategies, and skills. Research on self-evaluation and self-representation in regard to intellectual functioning is related to this aspect of hypercognition (e.g., Demetriou et al., submitted; Harter, 1990).

Working hypercognition refers to a cybernetic cycle of on-line self-monitoring and self-regulation processes that enable the individual to efficiently and accurately activate her cognitive system according to the requirements of the moment. These processes are guided by the three models summarized above.

The processing system

At the intersection of these two basic levels is the processing system. According to the theory, the processing system is a three-dimensional construct. It involves *speed* (the maximum speed at which a given mental act can be efficiently executed), *control* (the maximum efficiency at which a decision can be made about the right mental act to be executed according to the moment's requirements, as indicated, for instance, by response times to stimuli involving conflicting information), and *storage* (the maximum number of information units and mental acts the mind can efficiently activate simultaneously) (Demetriou et al., 1993, Studies 4 and 5). In a sense, the processing system may be seen as a dynamic field that is always occupied by elements coming from both of the other hierarchical levels, in proportions which vary from moment to moment. Specifically, the input to this system is environment-relevant information, skills, and processes, which pertain to an SCS or something equivalent. Their orchestration, their processing, their evaluation, and the evaluation of the outcome of their processing is under the control of the hypercognitive system. We would argue here that working hypercognition is the management system which is responsible for the management of the processing system. Thus, working hypercognition carries over to the processing system, so to speak, both the person's personhood and the person's more general views about the mind. We have presented extensive empirical evidence in support of the architecture of mind proposed above (Demetriou et al., 1993, Study 5; Demetriou et al, submitted, Study 2).

It may also be noted that cognitive neuroscience findings are in line with this architecture. For instance, Changeux (see Changeux & Connes, 1992/1995) has recently argued that the brain is organized so as to be able to process information that correspond to the three hierarchical levels of apprehension proposed by Kant, that is the level of perception, the level of thought, and the level of reason. As they were defined by Changeaux, these three levels correspond to the level of the biologically primary kernel elements involved in the various SCSs, the level of the biologically secondary processes, foundational theories and concepts involved in the various SCSs, and the hypercognitive system, respectively.

The fundamental causes of development

The development of any system implies (i) increasing skill in avoiding errors in its operation (ii) increasing efficiency in using the system's resources, and (iii) increasing the system's field of operation relative to an ideal field, that is, relative to all elements that might be brought under the control of the system. Thus, if it is to take place, development requires (a) a mechanism furnishing examples of characteristic patterns of relations of the various domains of reality that may be taken as starting points of development, (b) a recording device that can register side-by-side both the examples of the correct and the alternatives, and (c) a right-and-wrong marking device which can capture the deviations between the correct and the alternatives. We suggest that the architecture proposed by our theory is the minimum architecture needed if all three requirements above are to be satisfied.

Specifically, the SCSs of the environment-oriented level of knowing, by construction, function as knowledge extraction mechanisms attuned to specific patterns of information that generate some kind of accurate information about the environment from the beginning of life. That is, the theory assumes that each SCS involves inbuilt structures that abstract specific types of meaning from corresponding information structures once a minimal set of conditions are met. These are the kernel elements of each SCS mentioned above. This interpretation of initial meaning making is consistent with modern infant research which suggests that the fundamentals of categorical (Soja, Carey, & Spelke, 1991), quantitative, causal (Starkey, Spelke, & Gelman, 1990), spatial, (Landau, Spelke, & Gleitman, 1984), and social understanding (Trevarthen, 1977) are present from the very first months of life. Thus, the kernel elements function as mental yardsticks that can be used for the evaluation of the more complex and/or less accurate products of the application of the same knowledge extraction mechanisms, which may be due either to the presence of irrelevant or misleading cues in the information structure or to failures in the application of the structure as such. For instance, a system that somehow always «knows» that numerosity is constant under certain conditions, say when we have sets with less than four elements, will seek to understand why it does not appear to be constant under certain other conditions, say when an elongation transformation has been applied to one of the sets. Thus, the system is self-corrective because construction always involves a grasp of some aspects of the true state of affairs. In Gibsonian (Gibson, 1979) terms, the fundamentals of each SCS is automatically abstracted from the SCS-relevant affordances of the field of the environment concerned. Responding to the affordances guides the system to modify «knowing assumptions» that do not fit. Evidently, this assumption renders development a process of mutual validation of concepts in which the older and more basic ones, which have a higher level of confidence, help check, compare, select, modify, or reject the newer, frequently more complex ones, which have a lower level of confidence.

However, in order to be able to check, compare, select, modify, and reject, any system must be able to monitor its own activity, the products of its activity, and somehow be aware of both the monitoring processes as such and their products. It is only under this condition that divergences between two or more alternatives can become known so that errors can be marked and patterns of error-marking activities can be abstracted and stored for future use. In our theory, this is the responsibility of the hypercognitive system. Because of its recording, monitoring, regulation, and selection processes, the hypercognitive system contributes to all three main aspects of development noted above. That is, on the one hand, it generates evaluation or validation criteria that can be used by the thinker in order to avoid mistakes from the beginning, thereby increasing efficiency through sparing of resources. On the other hand, it establishes increasingly powerful interpretation, processing, and action networks that can be called upon in the future, thereby expanding the field of application of the environment oriented SCSs. In fact, our theory claims that logical reasoning is the product of the hypercognitively guided interaction between reality referenced representations (see Kargopoulos & Demetriou, in press, for a detailed discussion of the processes leading from reality-referenced representations to logical reasoning schemes).

The conception of change advanced above differs in two basic ways from traditional conceptions. First, it locates the origins and the main directions of developmental change in the structures involved in the architecture of the human mind. Second, it suggests that the products of developmental change at any given moment are never entirely new relative to the past because they grow from them as adjustments of present «tentative alternatives» to core or prototype concepts that define a structure as it represents «standard affordances» in its own environment. The changes discussed here may be seen as micro-adaptations in the tuning and the applicability of rules, strategies, and ideas about the environment.

Types of change

The analysis of the origins of change attempted above suggests that there are three different types of change that the developmental psychologist needs to study: (1) changes within structures, (2) changes in the relations between structures within a hierarchical level, and (3) changes in the relations between hierarchical levels. Below these different kinds of change will be discussed in some detail. The aim will be to show why each combination of change occurs, how does it occur, and how it can be studied and modelled.

Changes within structures

Changes within structures affect the relations between the elements that by definition pertain to the same SCSs. They are thus concerned with the same reality domain. For example, in the quantitative SCS, the integration of the representation of numerosity-affecting operations, such as addition or subtraction, with the representation of numerosity-irrelevant operations, such as changes in the spatial distances between the elements of a set, pertain to this category. Changes of this kind may result in an increase in the field of application of the structure, because they enable the person to apply the structure in areas of the structure's domain that were out of reach before the integration. For instance, in the example above, numbers larger than four can be conserved. They also result in a better focusing of the elements involved in the integration. For instance, the integration of the operations mentioned above enables the individual to understand that longer may usually imply more, but this needs to be qualified by other considerations as well.

Changes within hierarchical levels

Changes in the relations between different structures within a hierarchical level refer to mapping an element from one structure, say the quantitative, onto an element taken from another structure, say the causal, or the spatial. This kind of change is very different from the changes within structures discussed above. Their main difference lies in the fact that they are concerned with entities which represent different domains of reality, they involve different computational or operational rules and algorithms, and they may even require different symbol systems to represent their domains and sustain their computational functioning. One may refer here to changes that affect the relations between the quantitative and the spatial or the relations between the quantitative and the causal SCS. For instance, we know that a basic characteristic of the numerical domain is continuity in the succession of number elements. Counting natural numbers can go ad *infinitum*. On the other hand, a dominant characteristic of causality is its discontinuous character. That is, the presence-absence of the cause may correspond one-to-one with the presence-absence of the effect. Despite this basic difference, however, we do invoke the world of quantities to understand and specify the causal world. However, interrelating these domains is usually more difficult than interrelating components within the same system. Thus a special code is required that can be used for the interconnection between the different domains. This code needs time and effort to be constructed.

Changes across hierarchical levels

The picture becomes much more complex when we come to changes regarding the relations between elements which belong to different hierarchical levels. In this case, the change in a given element at one hierarchical level may open the way for structural changes at another organisational level, but the relation between the two elements is not affected as such.

A classical example of this type of change is that which affects the relations between the dimensions of the processing system, that is, speed of processing, control of processing, and working memory, on the one hand, and various domain-specific abilities which belong to the SCSs, on the other hand. The idea is that a change in any of the parameters of the more fundamental level of the cognitive architecture opens the way for the two types of structural reorganisations specified above, that is the changes within or across structures either at the level of the SCSs or the level of hypercognition. Specifically, Pascual-Leone (1970) was the first to show that ascendance through the hierarchy of Piagetian stages is caused by a systematic enlargement in the person's mental power, which is defined in terms of the number of information units that the person can mentally activate simultaneously. In the following years many scholars have demonstrated the relation between the changes in the various parameters of the processing system and the changes that occur in various conceptual domains (Case, 1992; Halford, 1993; Kail, 1988; Demetriou et al, 1993).

A similar type of transfer of change across hierarchical levels has been observed in the relations between the hypercognitive system, on the one hand, and the processing system or the environment oriented systems, like our SCSs, on the other hand. In fact, the recent proliferation of research on the effects that metacognitive training may have on various conceptual domains, which is very popular among educationally oriented scholars, highlights this type of change transfer across the levels of mental architecture (see Bockaerts, in press). That is, it indicates that imparting on the student a given metacognitive strategy or skill will beneficially affect the functioning of domain-specific skills or processes.

The discussion about developmental causality has shown that each system can function as cause of change in the other systems. However, the forms and the magnitude of change is not always the same. The change which originates in any of the general systems must be different in kind from a change that originates in any of the specialised spheres. Moreover, the change which transcends the boundaries between different spheres may be different in nature from the change which is confined within the same sphere. Therefore, one is justified assuming that different types of change take place through different mechanisms. Below we will discuss three types of mechanisms. Specifically, we consider mechanisms which transfer changes (a) across the hierarchical levels of the mental architecture, (b) within hierarchical levels, that is, from the one SCS to the other or from the one subsystem of the hypercognitive system to the other, and finally (c) from the one component to the other within a given SCSs or within the hypercognitive system.

Mechanisms of change

A number of authors have provided valuable insights into the nature of the mechanisms that are responsible for cognitive developmental change. Prominent among these authors is Piaget (1975) himself, Flavell (1972), and Fischer (Fischer & Pipp, 1984). The discussion below about mechanisms of change will draw considerably upon the ideas of these scholars. However, it needs to be pointed out that we will attempt to differentiate these ideas so that they can fit with the assumption of a three-level mental architecture. That is, we will attempt to show that different types of change in the relations between mental entities within and across the levels of mental architecture require different mechanisms to be effected. Thus, to avoid confusion, new terms will be used here to denote the different mechanisms. These terms aim to emphasise the position advanced in this paper that changes affecting different levels of the mental architecture or different structures within a level are effected through different mechanisms and that, therefore, the mental architecture constrains the dynamics of change.

Mechanisms for transferring change across and within hierarchical levels

A change in the processing system is nothing more than the acquisition of some extra but unshaped possibilities. For example, an increase in speed of processing or an enlargement in the span of working memory does not imply that all skills or concepts that could be constructed because of the extra speed or the extra span will automatically come into existence. Likewise, a change in the hypercognitive system is nothing more than a global re-orientation of the cognitive system to reality or to itself. For instance, when persons become aware of the limitations of their own working memory, they are virtually able to copy or construct strategies that would help them overcome these limitations and thus acquire and store information better than before. However, the transformation of the potentialities afforded by a change in the two domain-free systems into actual strategies, rules, operations, concepts, and skills in each of the various SCSs needs time, effort, and practice over domain-relevant examples for a very simple reason. The right-and-wrong-marking processes that constitute the basis for the expansion of truth-kernels into new domains cannot be practised in the void. The examples are needed as the raw material out of which new units can be created, which will transfer the kernel to new domains or invest it into new symbol systems. Old mistakes will be abolished because they will be found to conflict with the kernel. It is plausible to assume that this process is implemented through a number of distinct mental actions. These mental actions may be considered as the mechanisms that are used to implement the potentialities afforded by changes at one level of the cognitive architecture into another level.

Interjunction is one of these mechanisms. It refers to the construction of a new mental unit by establishing relations between units already available. However, the new unit does not displace or substitute the units involved in the construction. Thus, this mechanism is particularly apt to describe the establishment of relations between different SCSs, which, although necessary for the solution of complex problems that require the activation of more than one SCS, do not affect the functional autonomy of the SCSs.

The construction of new mental units through interjunction presupposes a change in the processing potentials or the monitoring and regulation strategies available that would enable the individual to envision the to-be-constructed units together and work out their possible connections that would result into the new construct. However, a change in the processing or the hypercognitive system would not suffice to generate particular interjunctions. For this to occur, two further requirements would have to be met. First, there must be a need for it which springs from the fact that already available solutions to a problem are recognised as irrelevant or insufficient. Second, the search for a new solution results in the identification of two or more concepts, operations, or skills as tentatively relevant to the problem and to their recognition as somehow consistent with the kernel element that guides the right-and-wrong-marking process. If these two requirements are met, the concepts involved will somehow be bridged together via the kernel element. An example of interjuction would be the use of graphical representations, which belong to the spatial SCS, to express covariation relations, which belong to the quantitative SCS. Another example would be the use of algebraic functions, which belong to the quantitative-relational SCS, to express causal relations. Evidently, interrelating these abilities does not affect the autonomy of any of them nor does it lead to their extinction. However, it broadens the scope of the problems that the person can represent and process.

Interweaving. The integration of previously unrelated mental units within an SCS for the sake of the construction of a new mental unit may be effected for the same reasons and in the same way as interjunction. However, integrating units within SCSs may engender a preference for the use of the new unit and an ensuing reduction in the isolated use of the units involved in the integration, although these units may still be available to the thinker. Thus, we propose the term interweaving to denote the mechanism which blends the units involved intimately and it alters their probability of use in favour of the new unit. For example, the interweaving of hypothesis formation with the isolation of variables ability within the causal-experimental SCS will result in the model construction ability. Although each of the two specialised integral abilities may always be present in itself, the model construction ability, once established, will dominate on the other abilities whenever the individual will have to deal with a problem which requires any of them (see Demetriou, Efklides et al, 1993).

The construction of new mental units on the basis of already available units within an SCS frequently results in the disappearance of the units involved in the construction. An example here would be the integration of the understanding that natural numbers follow one another in a particular way with verbal counting. Once this construction is established, it is improbable that thoughts about the succession of numbers can be effected without activation of the number name sequence or that stating this sequence can be free from a representation of the succession of numbers. We propose the term fusion to refer to the mechanism which generates new mental units within SCSs which absorb their building blocks thereby causing their extinction.

A mechanism twin to fusion is *deletion* or *abolition*. This mechanism is responsible for the rejection of old strategies, skills, etc., and the empowerment of the new ones. Such a mechanism is particularly useful especially at the beginning of the acquisition of a new strategy when the tendency for the application of the old strategies is still very strong. This mechanism is needed to ensure that the individual will avoid applying the old concepts or strategies instead of the new ones when she will have to deal with relevant problems. A classical example of abolition is the rejection of quantity judgements on the basis of spatial criteria once the quantity-relevant structure is established.

Evidently, the functioning of all four mechanisms described above depends on a kernel element in some way. Specifically, if two mental units are to be interjuncted, interweaved, or fused they need to be somehow consistent with each other. In turn, to be found consistent, they must reproduce to a minimum degree the defining characteristics of a kernel. For instance, the graphical representation of a relation of two variables requires bridging the understanding of number sequences with the understanding of spatial succession. However, underlying both of these two understandings is a more fundamental understanding: namely that something is constant in both cases, for instance ordinalities in the first case and succession of points in space in the second case. Likewise, a mental unit, if it is to be abolished as a means for the interpretation or the solution of a problem, it needs to be envisaged together with the kernel and to be recognised as inconsistent with it. We have argued elsewhere that these comparison processes are based on analogical reasoning (Demetriou, 1996, Demetriou et al., submitted).

Developmental hypermechanisms

The mechanisms discussed above may explain how new cognitive units are engineered on the basis of older units available. That is, these mechanisms are involved in the production of a new mental unit on the basis of or out of mental units already available. However, these mechanisms do not explain how the new units, once created, get stabilised, identified, and stored so that they can be preserved, recognised, and recalled in the future, whenever the need for them arises. To make the difference clear between the conception of a new idea and its preservation, one may refer here to the rather common experience of losing, temporarily or permanently, ideas that somehow «pop into the mind» unless they are systematically processed after they are constructed. In fact, studies of highly creative persons in science suggest that these persons, being aware of the danger of losing a newly conceived idea, were very careful to isolate themselves when intensively working on a problem (Ochse, 1990). Thus, it seems that we are in need of mechanism able to ensure that a newly created mental unit will stay alive.

We propose that one of the reasons which cause the dying out of new mental units is their failure to be connected to a symbol which will make them identifiable and mentally manipulable. Therefore, the endurance of new mental units depends on a process of *symbolic individuation*. This is a process which pairs newly generated ideas with specific symbols (Demetriou, 1993). These symbols, which may be idiosyncratic or conventional, may be regarded comparable the process of *identity ascription* to a newly born individual. That is, a name is given to the newborn and all information which is necessary to minimise the possibility that this individual will be taken as somebody else. This information also ensures that this individual will be integrated into the family tree of his parents and his relatives.

The process of individuating newly constructed mental units through their association with a symbol may vary considerably in as far as *originality* (e.g., a new idea may be defined in reference to an already available word or expression of one's natural language or it could be defined in reference to a new word or symbol), *completeness* (i.e., the degree to which the symbol used is able to express the various dimensions of the idea), and its *communicability* (i.e., the degree to which the new idea can be communicated to other individuals) is concerned. Our knowledge of these three dimensions of symbolic individuation as a mechanism of cognitive development is practically non-existent.

The reader may wonder how the mechanisms described above compare to processes described by other scholars in cogitive and developmental psychology. At a general level, all of these mechanisms seem somehow related to Piaget's (1975) reflective abstraction. In a sense, it could even be said that these mechanisms specify how reflective abstraction is effected at the different levels of the mental architecture or when it is activated to generate new concepts out of different kinds of structures. Likewise, classical cognitive psychology speaks about general processes of cognitive construction, like semantic networking at various lavels of depth or different kinds of encoding processes, which are used to shape and reshape concepts and their relations. The mechanisms of change proposed here might be taken as the implementation of these processes in the context of a theory which views the mind as hierarchical and multidmensional rather than as reducible only to general processing mechanisms. However, how the concepts advanced here relate to these other traditions of psychology is a matter of future theoretical and empirical inquiry and it is beyond the scope of the present paper.

The subjective and inter-subjective aspects of change

The discussion of change attempted above focused on the individual as a system primarily *undergoing* change. However, the three-level architecture of mind proposed by our theory implies that individuals do not only interact with the environment and undergo changes as a result of these interactions but they also somehow register both the interactions with the environment and the ensuing changes themselves. It is only under this condition that the individuals would be able to take charge of their own development, at least to a certain degree, and direct it towards goals which are considered important for themselves. At the same time, however, developing individuals do not live or develop alone. It is trivial to argue that each individual's development is monitored and regulated by other individuals who themselves may be undergoing development. Therefore, developmental change has a subjective dimension and an inter-subjective dimension which both need to be explored in regard to how they emanate and fluctuate and how they loop back thereby affecting change itself.

The subjective aspects of change. These refer to the experiences and the responses evoked in the person by developmental changes. One may ask three kinds of questions in this regard. That is, questions regarding the (i) cognitive (e.g., do the persons take any notice of the changes they undergo?), (ii) the emotional and motivational responses to change (e.g., does the change of this or that kind create feelings of uneasiness, uncertainty, and insecurity, or feelings of increasing efficiency and satisfaction?), and (iii) the actions that one may take to cope with these responses (e.g., when the persons recognise and/or feel that they undergo change, do they take actions, mental or real, aiming to affect the process of change, in the sense of modifying its course, rate, tempo, scope, direction, or products, in ways that would not occur if there was no recognition of the change or if no feelings were evoked by the change?).

The inter-subjective aspects of change. It is commonly accepted that an individual's development is affected by the other individuals this individual is interacting with, particularly those individuals who are important in a person's life, like parents and teachers. Strange as it might seem, however, there is practically no research known to this author on how change as such is recorded and represented by these individuals and on the possible effects that these representations might have on these individuals' attitudes and behaviour towards the developing person. In fact, all of the questions raised above in regard to the subjective aspects of change may also be raised at the inter-subjective level. Granted, we recently have a rise in the interest about parents' ideas about development (Goodnow & Collins, 1993) and about their knowledge of their children's competencies. However, there is no research and theorising on the parents understanding of their children's change as such.

When we come to the inter-subjective level an extra factor of complexity is added. This is the relation between the developing person's cognitive, emotional, motivational, and copying responses to change and the other persons' corresponding responses. Specifically, are, for instance, the parents' responses to their children's changes similar to or different from the children's responses to their own changes? Understandably, there is a dynamic loop here such that a developing person's changes and the way these changes are represented and responded to by the person affect and are affected by the parents' representations of and responses to both the changes themselves and their representation by the developing person.

In conclusion, the assumption here is that individual development is an abstraction which does not actually exist. That is, the changes occurring in an individual are in fact part of overlapping cycles of *co-development.* A cycle of co-development is the dynamic situation in which the changes which occur in an individual affect and are affected by the changes which occur in other individuals in the cycle. A given individual may be part of a number of cycles of co-development, such as the family, the classroom, and the peer group. Thus, we can even consider each individual as a transducer of developmental pressures from the one cycle to the other. Under this assumption, change becomes the dominant state of persons' life as it circulates across cycles of co-development through them.

Conclusions: The general character of development

According to the analysis above, development is possible because of two inter-dependent reasons. That is, because a person's mind is multisystemic and multistructural and because it co-develops with other minds. That is, at the level of the person, a change in any component of mind triggers a whole set of changes aiming to re-institute the functional tuning between the component that has changed and those related to it. In this process, the system makes use of kernel elements that can ensure that the construction process will preserve a field's defining notions and organisational principles. At the inter-personal level, a change in one person in a given cycle of co-development may cause changes at the subjective or the metasubjective level in any of the other persons in the cycle. These changes may then loop back and facilitate, obstruct, or divert the change in our target person. Thus, any change is regarded as a potential radiator of growth pressures on both its neighbouring components within the system and on other individuals who participate in the same cycle of co-development. The eventual result is of course a function of several crucial factors.

At the level of the individual, the nature of change depends upon the specific system that initiates a chain of changes and the condition of the other systems at the given period of time. This last factor is important because it determines the readiness of the other systems to move from their present state and follow the forerunner. For instance, it was argued before that developmental theorists agree that a change in the general processing system raises the general potential of the organism to assemble general strategies and grasp the relations between SCS-specific units which would be impossible at the previous functional level of the processing system. Nevertheless, this is not always the case. Our analysis of individual change patterns of the subjects tested on a number of tasks addressed to the various dimensions of the processing system and several SCSs showed that a change in the speed or control of processing or in working memory does not always result in changes in the SCSs (Demetriou et al, 1993).

This evidence is congruent with the assumption that the massive changes that have been associated by developmental theory with major stage shifts are possible when the changes in one of the systems accumulate up to a certain level, and then a change in another system occurs that functions as a catalyst which triggers the reorganisation of mind as a whole at a new representational or structural level (Demetriou et al, 1993). The changes occurring at crucial developmental turning points, such as those leading from sensori-motor to representational intelligence at about the age of two years or from concrete to abstract representations at about the age of 12 years, seem to be of this variety. For instance, the changes in the processing system between 9 and 11 years create the critical mass which is ready to be catalysed by the change in the hypercognitive system which, at about the age of 11-12 years enables the pre-adolescents to take a suppositional stance towards themselves and reality and accept to work with working models of reality as such rather than with face-value representations of reality.

However, once a major change has occurred, each of the various systems tends to draw upon itself as it moves to approach its final state. A consistent finding of studies which explored the dynamic relations between successive levels which expand over a number of years both within and across developmental sequences is that the subsequent levels of a sequence depend much more on the preceding levels of this sequence rather than on the preceding levels of another sequence (Demetriou et al., 1993).

Is then development a continuous or a discontinuous process? It is both. If viewed from the point of view of its end-products, development is discontinuous. That is, a major representational shift such as those mentioned above may be seen as a cutting point which demarcates the end of one developmental cycle and the beginning of another. The age phases co-inciting with these changes are usually regarded as phases during which there is an acceleration of development. This acceleration is regarded as an indication of the fact that the cognitive system is raised into a new level of functioning or that the possibilities of this level enable the individual to quickly acquire new abilities in various domains. Thus, discontinuity has a double meaning: (i) it refers to changes in the rate of change and (ii) to transformation in the kind of mental process that the cognitive system can execute and the kind of concepts that it can construct.

However, if viewed from the point of view of the dynamics underlying structural changes, development appears to be continuous rather than discontinuous. This is so because of the very nature of the mind itself. Being both an open and self-regulated system, it is always in a state of micro-adaptations. Thus, to the extent our measures are refined enough to spot these micro-adaptations between different blocks of mental units, development would be shown a continuous process. This for two reasons. First, in regard to within structure changes, Siegler (1995) was able to show, by using the microgenetic method that he promoted himself, that, within a given time window, there is always a kind of cognitive fermentation. That is, Siegler showed that at any time some ways of thinking are prevalent at the beginning and then decrease in frequency; others are very weak and infrequent at the beginning but they gradually increase in frequency until they dominate; other remain weak and infrequent although always present and still others fluctuate between being frequent and infrequent throughout the time window. Second, it is equally difficult to decide where to draw the cutting line between different developmental levels even when these developmental levels appear qualitatively different. We saw that in these cases the acquisition of the phenomenological characteristics of the higher developmental level are prepared by changes in the characteristics of functions or processes which reside at a different hierarchical level of the mental architecture which occur at a previous age phase. A pertinent example here are the changes in the dimensions of the processing system from 9 to 11 as a precursor of the changes in the level of functioning of the various SCSs from 11 to 13 years of age. Therefore, the discontinuity in development is a phenomenological concept which has some meaning only if examined in reference to how the observer sees the products of development once it has occurred. It does not describe «hot development», one might say, as it occurs.

This conception of development as being continuous and discontinuous at one and the same time brings our theory close to the modern analysis of development in terms of dynamic systems theory (van Geert, 1994). We would anticipate that lending the two approaches to interact would highlight phenomena that at present remain obscure. On the one hand, dynamic systems theory provides the framework and the methods that may be used to spot what change in what component can lead to a major (catastrophic) transformation of the mind. On the other, our theory provides well defined parameters and domains of mind on which one can test the general catastrophe models to see how they apply on cognitive development.

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