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Cambridge University Press
0521825792 - Cognitive Developmental Change: Theories, Models and Measurement
Edited by Andreas Demetriou and Athanassios Raftopoulos
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Introduction
The what, how and why of developmental change: the emergence of a new paradigm

Andreas Demetriou and Athanassios Raftopoulos

This book presents current theory and research on cognitive change. Chapter authors were invited to discuss cognitive change from the perspective of its three main aspects. Its object (*what* changes in the mind during development?), its nature (*how* does change occur?), and its causes (*why* does change occur, or, in other words, what are the factors, internal and external, that are responsible for cognitive change?). Obviously, these are both old and fundamental questions and all theories of development attempted to answer one or more of them. Piaget was the first to provide a full set of answers to all three of these questions. His answer to these questions can rather easily be summarized as follows: operational structures (what?) change through reflecting abstraction, which organizes the results of assimilation and accommodation (how?), because of maturation, cultural influences, and self-organization (why?) (Piaget 1970, 2001). The rate of change during the course from birth to maturity varies systematically, accelerating and slowing down at different phases, so that cognitive development appears to be stage-like. In a sense, this summary of Piaget's theory is also an accurate summary of the present volume. If this had been the whole story it would have been nice because our task of writing an introduction to the book would have finished here. Fortunately, for the field at least, this is not the whole story. We have come a long way since Piaget in our knowledge about all three aspects of change and therefore an introduction is indeed needed.

Naturally, the twelve chapters included in the book overlap to a large extent, because they are driven by the same three questions noted above. However, the answers and emphasis differ, depending upon each chapter's particular epistemological assumptions, the aspects of the mind it focuses on, and the methods employed. Overall, the book involves three sections. Chapters in the first section present, or emanate from, current models of cognitive development, with an emphasis on change itself. The chapters of (1) Demetriou, (2) Raftopoulos, (3) van der Maas, Jansen and Raijmakers, (4) Schwartz and Fischer, and (5) Torbeyns, Arnaud, Lemaire and Verchaffel belong to this set. These chapters focus more on the *what* or *how* of change and leave the *why* question in the background. Chapters in the second section focus on the methods or factors that induce or cause cognitive change. This section contains chapters by (6) Lewis,

(7) Saxe, (8) Griffin, and (9) Adey. Naturally, these chapters focus on the *how* and *why* questions and leave the *what* question in the background. Finally, the chapters in the third section focus on methods, mainly statistical and technical, that can be used to capture, demonstrate, specify and model change. These are the chapters by (10) Grigorenko and O'Keefe, (11) van Geert, and (12) Gustafsson. These chapters are more related to the *what* and *how* rather than the *why* question.

In this introduction, we will attempt to integrate the answers given to the three questions in all chapters into a common framework. The aim of the discussion is to set the scene but also to facilitate the reader to move beyond the particulars of each chapter by pinpointing the common underlying assumptions about cognitive developmental change that dominate current research and theorizing. In the pages below we will first try to specify the general trends that run through the whole volume in regard to the general conceptions of cognitive change. Then we will summarize and discuss each of the various chapters belonging to the three sets mentioned above. Finally, in the concluding section we will integrate the answers given by all chapters to our three guiding questions.

From the classical to the dynamic conception of cognitive change: the emergence of a new paradigm

All the chapters in this book show that modern cognitive and developmental psychology are shifting away from classical approaches to studying developmental phenomena to a more dynamic approach. The classical approach is based on the standard conception of the cognizer as one who receives inputs from the environment, builds internal representations of relevant aspects of the environment, processes these representations, and based on the outcome of this process acts on the environment transforming it. The cognizer and the environment form a system consisting of two independent entities that interact.

Cognizers have stored concepts and have competencies that allow them to interact with the environment. These competencies can be measured by means of various experiments; the subject matter of developmental psychology is the study of changes in these competencies. Thus, it is assumed that the subjects in an experiment have a salient competence that psychological experiments are designed to examine and measure. Of course, various factors, including measurement error, can intervene in the course of the experiment and affect the performance, which thus deviates from the true score that would have been achieved had the subject had the opportunity to display her competence unperturbed by other external factors. Thus, what the experiments actually measure is the performance not the competence of the subject. The extraneous factors that intervene bear no information on the studied phenomenon, and, in this sense, they distort the measurement. The only way to make a true measure of the competence, the salient capability of the subject, is to filter out the extraneous influences, that is, to remove the variability and reduce the data to their average. This is the guiding principle of the statistical methods employed by developmental psychologists in the classical tradition.

According to the emerging approach, cognizers do not simply receive input from the environment, store representations, process them, and output some action. This picture reflects not the way the mind operates, but the way we employ abstract symbolic structures. Instead, cognizers form a whole with the environment and dynamically interact with it. Cognizer and environment form an entangled or intertwined, soft-assembled, system. The problem-space and the opportunities for exploitation it offers become part and parcel of the processing procedure, and, in that sense, the mind transcends its biological confines and extends itself into the world, which it uses as a tool, to its own benefit. This means that the sequential order between input, processing and output relaxes and cedes its place to a kind of an 'action loop' ('an intricate and iterated dance in which "pure thought" leads to actions which in turn change or simplify the problems confronting "pure thought"' (Clark 1997, 36)) in which the relations among input, processing, and output become much more intricate and interrelated to be adequately described as a serial process.

In this sense, the strategies employed by the mind incorporate operations upon the world 'as an intrinsic part of the problem-solving activity' (Clark 1997, 67). The world no longer functions as a mnemonic repository in which we store information, but as the space on which we act, build external representations and systematically transform in ways that facilitate the mind in its tasks. Understanding cognition this way means that one has to abandon the view of the mind as an entity that is isolated from the world that builds and processes internal representations of the world, in favour of a conception of the mind as an entity embedded in the world. The mind so conceived, continuously and systematically uses external representations, thereby always remaining directly interleaved with the world.

Given the view of the environment as an extension of the mind and as an entangled part of the inseparable whole organism-and-environment, the behaviour of an organism can be properly understood only in a specific context. The context becomes a part of the problem-solving activity, and it is not just the space within which problem solving takes place. This is the contextualist or situated approach to cognition. According to this approach, a concept is no longer a static object in the mind, but an 'object' in the extended mind/brain-environment system. Since what transpires in this system is a loop of mutual actions, it is more proper to view concepts as processes that occur over relatively short time spans and that involve an interplay between the properties of the organism and the properties of the context.

If concepts are processes assembled on the basis of organismic and environmental components that form an interactive loop, the concept is necessarily characterized by a certain variation. Thus, each time a concept is being assembled when the cognizer engages in a problem solving activity within a specific context, the performance in the relevant task is by its nature variable and dependent upon the specific context. Since time is an intrinsic variable in dynamic phenomena, the context can never be the same, even if the same task is repeated over and over again within the same controlled experimental conditions; repetition by itself makes a difference. The variability and fluctuation in measurements are not due to extraneous factors that are irrelevant to the task; they are inherent characteristics of the phenomenon.

General models of cognitive change

The chapter by Demetriou presents his theory of the architecture and development of the mind. The theory attempts to identify and distinguish the modules and abilities involved in the mind, specify their functional common constraints, explicate their real time functioning, and, finally, map their developmental course and explain how and why they change with age. Thus, this theory describes, first, general processing potentials (such as speed of processing, attention, working memory), general problem solving processes (such as goal setting, planning, self-monitoring and self-regulation), and specialized capacity spheres (that is, those underlying the understanding of different types of relations in the environment, such as quantitative, causal, spatial, categorical reasoning, etc.). Then, it describes the developmental course of each of these processes and tries to explicate when, how, and why change occurs. Moreover, it involves premises concerned with individual differences in cognitive organization, functioning and development.

According to this theory, each of the processes involved is a developmental explanandum in itself. That is, any theory of development must explicitly describe and explicate the development of each of the processes mentioned above throughout life. However, it is also assumed that the development of each of the various processes depends, more or less, on the status and development of one or more of the other processes. Therefore, understanding the dynamic relations between processes is both a sine qua non condition for understanding the development of each individual process and an explanandum in itself. In this direction, the theory offers descriptions of the development of each process and a dynamic systems framework aiming to capture the contribution of each process to the development of the rest. Specifically, it is shown that general processing and representational constraints set general upper limits for each of the specialized problem solving and understanding capabilities of successive phases of development. A considerable part of change in the specialized processes (circa 30 per cent) is due to changes in the general processing capacities. However, for change to occur and stabilize in the specialized processes, special domain-relevant experience and practice is needed. If this is not available, general potentials may eventually remain unformed or unrealized. Thus, in their turn, the domain-specific capabilities determine, to a considerable extent, how much of the general processing and representational potentials are realized.

Growth and dynamic systems modelling are used to pinpoint these reciprocal interactions. This modelling suggests that the tighter is the interaction between processes the more stable and spurt-like or stage-like it is. Moreover, it also shows that there are systematic individual differences in the tightness of the interactions between processes, which, in turn, result in corresponding differences in the rate and stability of individual development. These differences are reflected in differences in classical measures of intelligence, suggesting that the dynamics of individual cognitive development determine, to a considerable extent, how much of one's abilities are put to efficient use relative to others.

The chapter by Raftopoulos aims to answer the question of how does change of present processes and abilities into more advanced processes and abilities occur within a dynamic context? The chapter attempts to explicate, in terms of a combination of connectionist and dynamic systems modelling, how and why change may occur in a cognitive system that involves the generalized and specialized processes described in Demetriou's theory. According to Raftopoulos, cognitive change results from external pressures on the system, which tries to accommodate them by transforming, combining, re-combining, refining and abandoning concepts and skills already possessed.

Since the terms 'concepts' and 'skills' are understood in the dynamical sense described above, the notion of attractor (the dynamical equivalent a prototype concept) and of basin of attraction (the dynamical equivalent of variations of this prototype) is introduced to capture better their dynamical significance, and cognitive change is described as a trajectory on the activational landscape of a dynamical network. The idea that change is to be modelled by means of transitions in the state space of a dynamic system is at the heart of dynamical theories of cognition. Raftopoulos argues that dynamic connectionism can account for the processes of change at the conceptual level by (a) explaining how these are implemented by means of changes in the landscape of the activation space of a network, that is, by change in the relations between attractors and basins of attraction, and (b) by proposing some well-defined neural network mechanisms that can account for these changes.

Raftopoulos focuses his discussion on the class of networks that may change their structure (add or delete units and/or change connectivity patterns) while they learn, in order to increase their representational power. However, there is the possibility that certain neural networks can and do increase their expressive power without changing their structure. Under certain circumstances, small changes in synaptic weights can cause a real phase transition. More specifically, dynamical theory provides an explanation of how qualitatively new modes may emerge, not as a result of structural changes in the network, but because of the internal function of a self-organizing system (Raijmakers 1997). In this case, it seems that only a single general mechanism of change needs to be posited, that of continuous and gradual small changes in the connection weights of a network.

The non-linear dynamics of a system can result in more expressively powerful structures by means of self-organization and of the non-linear dynamic governing the activation functions of their processing units. Such transitions from a lower to a higher level of complexity, when the control parameters of a system transcend a threshold and critical mass effects occur, abound in dynamical theory (Elman 1995; Kelso 1995; Thelen and Smith 1994). From these studies, a common thread emerges. The internal synergies of the coupled systems that interact and the underlying non-linear dynamics may result in phase transitions and in the emergence of qualitatively new, more complex, modes: 'Certain preferred collective states of the system are depicted as synergetic wholes that can be brought forth (but not programmed) by the action of some control parameter', Clark (1997, 473). These changes are manifest in a discontinuous, stage-like, increase of the level of performance of the system, that is, in dramatic changes in the output (behaviour). These transitions correspond to the state transitions of dynamical systems. In these cases, the values of control parameters change continuously and the changes may be arbitrarily small, and yet, they lead to an increase in the expressive power (measured as computational complexity) of a system.

In their chapter, Han van der Maas, Brenda Jansen and Maartje Raijmakers focus on the mechanics of transition to higher levels of understanding. They take the common balance as their domain of understanding and Siegler's rule system as a description of the sequence of successive levels of understanding the relations between the factors (i.e. weights and distances) involved. According to this system, understanding of these relations moves across a sequence of four main levels of increasing complexity such that higher levels integrate more fully the relations between the various dimensions involved (i.e. number of weights and distances from the fulcrum on the two sides of the balance). Van der Maas et al. examine the details of phase transitions across these levels and they show that the transition across some levels (from level I to level II) is a genuine phase transition that exhibits most of the catastrophe flags, and hence it is a discontinuous, stage-like transition. Variability and fluctuation in performance figures notably in their account. Subjects are easily perturbed when transition is likely to occur, and thus their performance is very sensitive to context effects.

The classical Rule Assessment Methodology (RAM) that Siegler applied to the problem of the balance scale detects only rules that are known a priori, as a result of a task analysis. According to this method, tasks of increasing complexity are constructed to map a succession of mental rules, supposedly applied by the thinker, so that each task can be solved by the application of one and only one rule of the hierarchy. Solving a particular task automatically allocates the thinker to the rule supposedly represented by the task. However, the authors argue, the child may use unobserved rules, which the RAM fails to detect. These 'hidden' rules play the role of latent properties, which correspond to the concept of a latent variable in Latent Class Analysis. A latent variable is the factor that acts as a common cause underlying the phenomena under study and which accounts for the observed pattern of association between the manifest variables. The unobserved latent property of proportional reasoning, for instance, determines the behaviour of a person's manifest indicators, her performance on the balance scale problem, for instance.

The application of latent class analysis reveals the existence of unobserved rules in the development of the understanding of balance scale tasks (such as the compensation rule and the buggy rule), that did not appear in Siegler's and others' accounts. Moreover, the latent classes reflect the structure in the observed data, unlike the rule classification of RAM and the connectionist analyses of the balance scale by McClelland (1995) and arise independently from the rules postulated in a theory. The analysis of the rules and their use, and the study of the phase transition from Rule I to Rule II, lead the authors to propose a restricted, overlapping waves model instead of the standard overlapping waves model of Siegler (1996), to describe the development of problem solving on the balance scale task. The model includes both waves that overlap to a great extent and waves that hardly overlap (hence its designation as 'restricted'). The former reflect the continuous aspects of the development of a given individual in the balance scale task, and the latter its stage-like discontinuous aspects. Rule I and Rule II, for instance, are non-overlapping waves, hence the discontinuous development from Rule I to Rule II. The use of catastrophe theory, finally, enables the authors to explain rather than assume the abruptness that characterizes certain developmental phenomena. Moreover, this analysis is embedded in the context of Anderson's ACT-R theory (Anderson and Lebiere 1998), which specifies the capacity constraints, the general problem solving mechanisms, and the task-specific concepts required by each rule. Obviously, this approach brings this chapter close to the work presented in this volume by Demetriou, Torbeyns et al., Griffin and Adey.

Variation of understanding over time and the development of specific tools for describing how people use groping and adaptation to build new knowledge is the subject-matter of Mark Schwartz and Kurt Fischer's chapter. They employ the microdevelopmental method and their aim is two-fold: (a) to explore understanding and variations in understanding over time as subjects confront new problems, and (b) to demonstrate how skills-analysis can account for the specific trajectories that students move through, when they reach more complex understanding of the parameters and their interrelations involved in these tasks. The microdevelopmental method ensures that, unlike what happens in most developmental frameworks that study long-term changes, change and understanding is studied under the perspective of short-term building of components for specific tasks. More specifically, they examine in detail the process of building understanding in two tasks, namely, building bridges and electrical circuits. Since the skill levels that individuals will construct are intricately associated with, and depend upon, changes in context and individual state, understanding is a dynamic situated process.

The performance in the tasks examined and the processes that lead to it are ordered developmentally along Fischer's (1980) systems of levels and tiers. The notion of functional level contradistinguished with the optimal level, and the notion of developmental range, prominently figure in their account. The functional level refers to the best the individual can do in the context of a specific task without support from her environment. The optimal level refers to the best the individual can do in the context of a specific task with support from her environment. An individual's developmental range is the interval between her optimal and functional levels. These notions emphasize the role of the learning environment, in its general sense, upon performance in a task and highlight its dynamical situational aspect.

It is worthwhile to note that the authors notice stages of regression; when subjects encounter a novel problem they regress in their strategies; that is, they use more primitive skills than those already included in their cognitive repertoire. The explanation of this phenomenon is that the subjects use the more primitive skills and not their more sophisticated ones in order to familiarize themselves with the new domain. One might attempt to explain this further by arguing that the subjects attempt to capture first the simpler regularities of the domain (let us call them first-order regularities) and then proceed to build more complex understanding based on these first-order regularities. In order to do that, though, they must use those skills from their cognitive repertoire that are better tuned to understanding the more basic, and hence less complex aspects of the phenomena: these are the less sophisticated skills.

The analysis of the task involving electric circuits nicely demonstrates this effect. This way, the more basic skills put in use in a new domain may be coordinated differently, and new more complex skills that suit better this specific domain may be developed. This would justify the authors' claim that 'microdevelopment is the process of recovering and reorganizing skills when confronting novel problems in order to construct new skills that are needed to meet the demands of the new problem' (Schwartz and Fischer, this volume).

The theme of cognitive variability as an important feature of human cognition throughout life is at the center of the contribution of Joke Torbeyns, Laurence Arnaud, Patrick Lemaire and Leaven Verschaffel. Cognitive variability means that several strategies can be used successfully either from the same subject on different occurrences of the same task, or from different subjects performing the same task. Torbeyns et al. discuss first various theoretical issues related to the information-processing approach to cognitive development with the emphasis being on Siegler's models. They also present and compare two research methods, to wit, the microgenetic and the choice/no choice method. Then, they apply these two methods to studying change in toddlers' strategy use in problem solving and change in children and adults' strategy characteristics in the domain of computational estimates.

Their conclusion is that cognitive variability is the norm and that the choice of strategies may be either progressive (the strategies adopted are more and more effective), or regressive (a subject who solves a task by using an effective strategy may for various reasons subsequently adopt a less effective or ineffective strategy). Strategy choice depends upon four factors: the problem features, the characteristics of the strategy, the situational constraints, and the individual differences. The main claim is that information processing approaches show that cognitive development should not be construed as a succession of modes of thinking, but as involving several modes of thinking coexisting and competing. Both progression and regression in the effectiveness of adopted strategies are therefore expected and indeed observed. Cognitive development proceeds gradually, with continuous changes in the repertoire of available strategies, their frequency, efficiency and adaptiveness.

The information processing tradition radically departs from the dynamic tradition discussed above, especially in the analogy that it draws of the mind as a serial computer that performs computations on symbols. However, despite this, Torbeyns et al. reach the same conclusion with regard to variability and fluctuation as van Geert, van der Maas et al. and Raftopoulos, namely, that variability and fluctuation are intrinsic to the phenomena under study and not the results of extraneous factors independent to the phenomenon.

Thus, variability and fluctuation in performance and thereby progression and regression is an emerging property of the natural dynamics of a system that is soft-assembled from constituents that interact in complex ways to form a complex system, which includes the immediate environment (recall that, according to Torbeyns et al. the strategy choice depends upon the problem features, the characteristics of the strategy, the situational constraints, and the individual differences). From this perspective, progress and regress are the result of the non-linear interactions of the subparts of the complex system. Neither of them can be explained solely in terms of the transformations of the developing organism's states; their roots lie in the interlocking of multiple context-dependent processes, both internal and external to the organism.

If we focus on each phase of development in its own sake and examine the developing person as a system, which is part of a wider system (its own environment), then development appears only positively. People function at multiple levels concurrently and thus there are various indicators for different aspects of growth of a given system. Hence, focusing on one indicator of the system may show regress when in fact massive positive changes have occurred. For instance, disappearance of stepping movements in the period three to seven months is accompanied by large positive changes in the development of the body and its control by the brain. Wrong use of words (e.g., the word horse to denote a shoe) coincides with a large expansion of vocabulary. Looking for an object at the wrong place in the A-not-B arrangement is accompanied by an expansion in memory capacity (Gershkoff-Stowe and Thelen in press).

Inducing and causing cognitive change: from description and explanation to practice

The four chapters in the second section present work that aims either to explain or induce cognitive change in reference to broad biological or socio-cultural causal factors. The first chapter, contributed by Marc Lewis, brings the dynamic approach from the organization of functional mental units to the organization of the brain itself and the interpretation of the relations between cognition and emotion. Lewis agrees with dynamic systems theorists (Thelen and Smith 1994) that what develops are cognitive and perceptual coherence, and how they develop is through the mechanism of selection of functional forms, of 'what works'. However, he points out that this account tells us only half of the story because it does not explain the why of development. That is, it does not explain why some forms work better than other forms. He suggests that emotions are responsible for the selection of forms that work because they index events that have acquired significance within the particular environments of family, community, culture and niche. That is, the emotional system is organized to guide attention, action, and thought according to what is proficient and useful, and this is how cognitive abilities emerge systematically in the service of functionality. Thus, Lewis elaborates on how emotion guides neural self-organization (1) in real-time cognitive processes, (2) along the path of cognitive development, and, finally, (3) along unique developmental pathways referred to as personality styles.

Lewis discusses the four levels in which the brain is organized, that is, the brain stem (a set of nuclei for programmed responses to internal and external events), the diencephalons (the thalamus and hypothalamus that process and route sensory input, providing a more detailed picture of the world), the