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Barrouillet, Pierre Noël

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Pierre Barrouillet *

Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Genève, Switzerland

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ABSTRACT

At the occasion of their fortieth anniversary, the Archives Jean Piaget, a foundation created by Bärbel Inhelder in 1974 for the preservation and promulgation of Piaget's oeuvre, invited in Geneva ten among the most prominent and influential developmental psychologists to the first Jean Piaget Conferences. Cognitive developmental psychology has undergone radical changes during these last four decades since the last formulations of Piaget's constructivism. In this double special issue, the invitees of the Jean Piaget Conferences elaborate on their own conception of developmental changes in a variety of domains and functions, offering a comprehensive overview of current theories of cognitive development.

Introduction

Jean Piaget, by the scope, depth and importance of his work, is undoubtedly the major figure of twentieth-century psychology. As Flavell, Miller, and Miller wrote in their textbook about theories of development: "theories of cognitive development can be divided into B. P. (Before Piaget), and A. P. (After Piaget), because of the impact of his theory on the theorizing that came thereafter" (Flavell, Miller, & Miller, 2002, p. 8), adding that Piaget had "the greenest thumb ever for unearthing fascinating and significant developmental progressions" (Flavell, 1996, p. 202). His direct entourage did not remain, of course, unaware of the prominence of his outstanding and unique contribution. In 1974, six years before Piaget's death, the late Professor Bärbel Inhelder, probably his most talented and devoted collaborator, took the initiative to create a research and documentation center, the Archives Jean Piaget,

* Faculté de Psychologie et des Sciences de l'Education, Université de Genève, 40 bd du Pont d'Arve, 1211 Genève 4 Switzerland. Fax: 0041223799020.

E-mail address: Pierre.Barrouillet@unige.ch.

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a private foundation for the preservation and promulgation of Piaget's publications and the vast literature he inspired. The foundation, allied with the Faculty of Psychology and Educational Sciences of the University of Geneva, has never ceased its activities, and after the recent donation by the family of the entire content of Piaget's office in his house of Pinchat in Geneva were he lived for about sixty years, the collections of the Archives Jean Piaget host almost all the manuscripts of the great Swiss psychologist nowadays accessible. In June 2014, on the occasion of their 40th anniversary, the Archives Jean Piaget invited to the University of Geneva prominent developmental psychologists to present their work as part of the first Jean Piaget Conferences. Piaget having set out the first major theory of cognitive development, the event was naturally entitled *Theories of development*. The present double special issue of *Developmental Review* extends this conference by gathering the contribution of its participants, who have been invited to present their most recent empirical and theoretical advances in the domain of cognitive development.

Theoretical evolutions after Piaget

Piaget's theory was so broad in scope though parsimonious in its number of theoretical constructs and postulates, it was so systematic in its approach and successful in discovering a range of unexpected developmental findings in a variety of domains that Flavell et al. (2002) did not exaggerate when describing an A. P. period in developmental theorizing. In large part, this period began when Piaget's work became more popular in North America, mainly through the influential books authored by Hunt (1961) and Flavell (1963), and came into contact with learning theory and the then emerging information processing approach. Much of the ensuing debates revolved around children's acquisition of conservations, and the putative role of learning and experience in this acquisition. According to Case (1985), the two postulates that provided the greatest difficulties were the idea that behavior at each developmental level is underpinned by logical structures, with different types of structures determining successive developmental stages, and that the transition from one type of structure to the other resulted from a process of equilibration through a mechanism of reflective abstraction. Horizontal *décalages* (the fact that two notions supposed to rely on the same structure present a systematic interval in their acquisition, such as matter and weight conservations), poor correlations among tasks assumed to pertain to the same developmental stage (Pinard & Laurendeau, 1969), and the lack of explanatory power of the notion of stage (Brainerd, 1978) undermined the idea of logical structure in a decisive way, while training studies suggested that cognitive disequilibrium triggering an equilibration process was not necessarily needed to access stable conservation understanding (Case, 1977). At the same time, factors such as language and cultural influences, which remained neglected in Piaget's theorizing, were assumed to shape cognitive development (Bruner, 1960; Vygotsky, 1962), while information processing approaches introduced, through the computational simulation of production systems, a rigor in theorizing that was then uncommon (Klahr & Wallace, 1976; Simon, 1962). Approximately at the same time, the emergence of new methods allowed for the investigation of cognitive processes in infants that went beyond Piaget's pioneering and influential contributions in this domain. As Piaget surmised "the explanation of cognitive behaviour by means of innate ideas is, in general, a facile and rather lazy solution, … however, after the excesses of explanation by learning alone, a return to nativism is to be expected" (Piaget, 1968, p. 978). Accordingly, the recent decades have been marked by an upsurge in nativist accounts of infant cognition and development leading to a modularist and domain-specific view of cognition (Cosmides & Tooby, 1994; Fodor, 1983) and the hypothesis that human beings come into the world endowed with some core knowledge to deal with especially relevant aspects of their physical and social environments (Baillargeon, 1994; Carey, 2009; Spelke, 2000).

Despite notable exceptions known as neo-Piagetian theories (Case, 1985, 1992; Halford, 1993; Pascual-Leone, 1970), these evolutions resulted in some abandonment of the notion of stage in describing and explaining cognitive development and in the appearance of domain-specific local theories aiming at accounting for the development of the main cognitive functions such as perception, learning, categorization, memory, language, reasoning, or problem solving. Nowadays, it seems that developmental psychologists no longer agree, as Case assumed in the eighties, "that any theory of development must ultimately provide an unified account of the changes that are revealed by tests of children's higher cognitive processes and by tests of their more basic processes and capacities" (Case, 1985, p. 50). Indeed, a general theory aiming at accounting for all the aspects of cognitive development from perception to abstract reasoning from birth to adulthood seems today out of reach. However, this is not to say that general mechanisms of cognitive development have not been advocated after Piaget (e.g., Siegler, 1996, overlapping waves in strategy choice, or Karmiloff-Smith, 1992, representational redescription). The first volume of the present special issue gathers contributions that propose general approaches in this sense, either by discussing the role and impact of some mechanism or process assumed to shape development in, at least potentially, a variety of domains, or by presenting a theory that sheds light on different areas of cognition and unifies key developmental findings. The second volume will present a series of articles focusing on domain-specific developmental processes, ranging from awareness, gesture, or memory to the understanding of quantities and natural, decimal, and rational numbers. Nonetheless, as the reader will rapidly discover, the distinction outlined above is largely arbitrary and mainly drawn for expository purpose, as both sets of contributions address at the same time general problems of cognitive development and their illustration in a significant domain of cognition.

The nativist option and evolved probabilistic cognitive mechanisms

One of the first rebuttals of Piaget's theory came in 1967 from a well-known study by Mehler and Bever on conservation of number. Children aged from 2 years 4 months to 4 years 7 months were presented with two rows both containing 4 clay pellets or 4 candies and were asked if the rows were the "same". Then, the experimenter added two objects to one of the two rows and modified the arrays in such a way that the resulting row of six objects was made either shorter or longer than the row of four. Mehler and Bever observed that the youngest children consistently pointed to the row of six objects as containing "more", even when this row was shorter. Surprisingly, this capacity seemed to progressively disappear with age to reappear around age 4. Even more surprisingly, this U-shaped developmental trend did not occur when the rows were made of candies instead of clay pellets, children choosing systematically the row of six when invited to take the row they wanted to eat. The authors interpreted these results as demonstrating that young children have the capacities to understand quantity conservation, an ability that would be temporarily overcome by perceptual strategies. Eventually, the child would develop an explicit understanding of his or her operations, reacquiring quantity conservation. The constant success with candies was interpreted as demonstrating that the perceptual strategy could be overcome given sufficient motivation to do so. Although these and other findings about understanding of quantitative invariance in young children did not remain without criticisms (e.g., Hunt, 1975; Katz & Beilin, 1976), the view that has prevailed is that "young children do know something about quantity and that there are conditions under which they can and do reason about quantity" (Gelman, 1978, p. 303). The recent decades taught us that "young children" could be replaced by "infants" in Gelman's statement (see Feigenson, Dehaene, & Spelke, 2004, for one of the clearest examples).

The findings presented by Mehler and Bever (1967) were so unexpected at the time and the candy-effect so attractive in many ways that Piaget's (1968) response remained in neglect. However, it has in retrospect an undeniable appeal. After having objected that the Mehler and Bever (1967) experiments have nothing to do with conservation (something that they agreed on in their reply), Piaget discussed their hypothesis that an innate kernel furnishes an immediately valid schema of quantitative evaluation that can be temporarily counteracted by misleading perceptual strategy, but that eventually brings about a return to the correct, innate ideas. He argued that if innate ideas can be so easily counteracted, they cannot consist of a real structure with hereditary programming, but can be no more than an innate form of functioning. And this is precisely what his own theory had always assumed: structures are derived from general coordination of actions that have permanent and innate functional mechanisms that intervene in the construction of numerical quantities. According to Piaget, a construction takes place that produces novelties, the idea of construction prevailing over that of preformation.

It seems that Piaget's rejoinder is in accordance with David Bjorklund's (2015) proposal in the first article of the present volume about adaptations and their development and the concept of *evolved probabilistic cognitive mechanisms*. After having analyzed the modernity of Piaget's view about adaptation, Bjorklund outlines the postulates on which the mainstream evolutionary psychology and the neo-nativist approaches are based. Both assume that infants are not born as blank slates but possess what are called *evolved cognitive mechanisms*, which are domain-specific cognitive modules shaped by natural selection to solve recurrent adaptive problems associated with reproduction and survival our ancestors faced in their environment. Bjorklund's main argument is that the surprising plasticity that leads to adaptation in development requires an amendment of the notion of evolved cognitive mechanism that would make this type of mechanism far more flexible than initially assumed, hence the notion of evolved probabilistic cognitive mechanisms. As the evolved cognitive mechanisms, they are information-processing mechanisms that have evolved to solve recurrent problems faced by our ancestors, but they are expressed in a probabilistic way, depending on the interactions between the organism and its environment at all the levels of their relationships, from the genetic to the cultural. Young organisms do possess domain-specific mechanisms sensitive to their environments as the neo-nativist approach assumes, but these mechanisms develop. Consequently, the form they will take through development is variable and susceptible to a range of potentially adaptive species-typical behavioral outcomes. Bjorklund illustrates the concept of evolved probabilistic cognitive mechanism through the development of face processing and prepared fear during infancy. The developmental analysis demonstrates that far from being born with preformed mechanisms selected by evolution to solve specific problems in a predetermined way (e.g., having an innate interest in faces or fear of snakes), human infants are endowed with perceptual biases that increase the chances that adaptive responses to evolutionary-relevant stimuli are acquired through development. Although Bjorklund notes how this conception is germane to the way Piaget conceived adaptation, it seems that a crucial difference remains in that the adaptive mechanisms postulated by Piaget were universal and thus domain-general in nature. The innate form of functioning he assumed involved general mechanisms of assimilation, accommodation and equilibration, whereas the evolved probabilistic cognitive mechanisms remain domain-specific, orienting the infant's attention toward some low-level perceptual patterns in their environment. However, as Piaget did, Bjorklund privileges development over preformation.

Conceptual and domain-general changes

As Bjorklund does in his article, Carey, Zaitchik and Bascandziev (2015) initiate a dialog with Piaget. They see his work as having two complementary thrusts, which are constructivism and stage theory. The thesis of the authors is that modern developmental cognitive science has gone beyond Piaget's insights by identifying constructivism with the conceptual changes best described by the theory–theory of development, whereas the age-related evolutions that Piaget explained within his stage theory are domain-general changes nowadays accounted for by the development of executive functions. Carey et al. illustrate conceptual changes in two domains, the intuitive theories constructed by children about the mind and about biology. The authors see a classic example of Piagetian construction in the developmental conceptual changes that take place between ages 5 and 12 within intuitive biology. They argue that the developmental discontinuity from an initial theory of the biological world in which children identify life with animals conceptualized as causal and intentional agents to a later vitalist theory of biology provides strong evidence for the constructivist hypothesis. This hypothesis is reinforced by the fact that, as the authors emphasize, there is no evidence or proposal that the concepts within vitalist biology are innate. They develop over several years and there are populations such as adults with Williams Syndrome who never reach its final stages. At the same time, there is strong empirical evidence that executive functions play a determinant role in this developmental change and are recruited in the construction of the vitalist theory.

Things are less clear for the theory of mind. Whereas the seminal investigations of the understanding by children of false beliefs led to the conclusion that there were developmental changes with strong discontinuities lending support to both a constructivist scenario (Wimmer & Perner, 1983) and the involvement of executive functions in this process (Carlson & Moses, 2001), subsequent studies considerably obscured this picture. Not only successes on implicit false-belief tasks have been reported in toddlers and infants (Onishi & Baillargeon, 2005), but also the relationships between executive functions and theory of mind have been the object of controversy in the literature.

Carey et al. conclude that Piaget's constructivism and Piaget's stage theory are still with us today, but more divorced than he assumed. Domain-general changes are nowadays conceived as resulting from the development of representational structures and computational mechanisms that are farther from the evolving conceptual contents than in Piaget's account. This analysis is pervasive. Piaget conceived the development of intelligence on the one hand and the construction of reality on the other (probably what Carey et al. identify with stage theory and constructivism, respectively) as the two inseparable sides of the subject/object interaction. The construction of the subject conceived as a structured set of schemes was closely united with the construction of the real as a coordinated set of defined attributes. What modern cognitive science suggests, and what Carey et al. argue when comparing the development of the theory of mind and of intuitive biology, is that the development of concepts for understanding the physical, biological, and social world is not a mere and direct manifestation of the evolution of abstract and domain-general cognitive structures as Piaget assumed.

Executive functions, domain-general-developmental changes and training effects

The development of the executive functions identified by Carey et al. (2015) as the motor of domain-general changes is directly addressed by Philip Zelazo (2015) in his article. Zelazo defines executive functions as "the set of self-regulatory skills involved in the conscious goal-directed modulation of thought, emotion, and action", providing an important foundation for learning and adaptation across a wide range of contexts. Their domain-general impact is attested, as Zelazo notes, by their predictive power in several developmental outcomes ranging from school readiness in kindergarten, school achievement, and social competences to better physical health, fewer drug-related problems or higher socioeconomic status. The article describes Zelazo's *Iterative Reprocessing* model that provides a framework for understanding at the behavioral and neurological levels the functioning and development of executive functions such as cognitive flexibility, working memory, and inhibitory control. Executive functions are conceived of as skills that modulate attention according to current goals through the formulation and maintenance in working memory of representations of action-oriented rules for directing behavior. Development occurs by an increase in rule complexity through a process of reflection that allows for more complex representations. This reflection, which occurs by actively considering one's situation, is made possible by an iterative reprocessing of the information held in working memory. This requires some degree of psychological distance from one's experience in such a way that more aspects of a situation can be noticed and integrated into a single representation (interpretation) of the situation. The resulting increase in rule complexity allows in turn for increases in executive function skills as they are typically measured by tasks as the Dimensional Change Card Sort (DCCS; Zelazo, 2006). At a cerebral level, it is assumed that rules of increasing complexity are supported by increasingly anterior regions of the prefrontal cortex.

In the same way as Carey et al. (2015) conclude that Piaget's notions of constructivism and stages "are still with us today", some of Piaget's legacy seems to be identifiable in Zelazo's theorizing. Indeed, Piaget explained domain-general developmental transitions by a process of equilibration resulting in the construction of new cognitive structures through reflective abstraction on the previous forms of mental functioning. The *Iterative Reprocessing* model and its process of reflection leading to a higher level of control and adaptive modulation of thought and action are not so far from the reflective abstraction postulated by Piaget.[1]In the same way as this reflexive abstraction leading to equilibration was triggered in Piaget's theory by the conflicts resulting from cognitive disequilibrium, the reflective process postulated by the *Iterative Reprocessing* model is triggered by the detection of conflict and uncertainty. However, there are also divergences with the traditional conception of reflexive abstraction. For example, the role of language through self-directed speech in the representation of rules and the development of self-regulation is more reminiscent of Vygotsky's (1962) views than the Piagetian orthodoxy in which language was seen, at best, as an auxiliary in intellectual development. In the same

[1] It is interesting to note that such a *reprocessing* was already advocated by Klahr and Wallace (1976) who hypothesized some *review* or *replay* of previous mental activities to detect consistent sequences of activities leading to new production systems for representing the detected consistency, a mechanism in turn akin to the metacognitive processes for identifying potential sources of amelioration in strategies postulated and simulated by Shrager and Siegler (1998). This regular resurgence of the concept of reflection on existing cognitive processes is striking and probably indicative of the enduring difficulty of developmental psychology to renew its theoretical tool-box when accounting for developmental changes.

way, the reflection postulated by Zelazo, with its increase in the number of attributes of the situation integrated in a single representation, seems to oscillate between what Piaget called simple abstraction, aimed at extracting attributes from the object, and what he called reflexive abstraction allowing for the extraction of the structure of our own actions on these objects. Another difference relies on the role attributed by Zelazo to training, with the assumption that brief interventions targeting reflection would be sufficient to improve executive functions and produce corresponding changes in neural functions, a role of training that Piaget would have probably denied. Constructivism being based on the idea that the benefit that the organism is able to gain from experience depends on its present level of development and its ability to compensate the potential disequilibrium induced by experience, a brief intervention has little chance to produce the lasting reorganization of cognitive structures on which domain-general developmental changes are based in Piaget's theory.

Understanding others, mentalism, and teleology

While Zelazo focuses on the developmental evolutions that could yield domain-general changes, Perner and Esken (2015) address the question of the mechanisms that allow individuals to make sense of their environment – what Carey et al. (2015) identified with the constructivist part of Piaget's enterprise – in one of the two domains they analyzed, namely theory of mind. One of the main assumptions of the theory–theory approach favored by Carey and her collaborators is that conceptual development mainly affects a small set of framework theories among which the theory of mind is of paramount importance as it allows humans to understand others and their actions. Carey et al. (2015) note that, among these framework theories, some are manifest cross-culturally and early in infant development, something that seems to be the case for theory of mind (Onishi & Baillargeon, 2005), which is assumed to constitute an example of the evolved cognitive mechanisms discussed by Bjorklund. Accordingly, its emergence could be traced back to the cooperative turn in evolution that Tomasello (2014) in his *Natural history of human thinking* situates in *Homo heidelbergensis* (between 200,000 and 600,000 years before our era), when hominids began to systematically engage in collaborative hunting. Perner and Esken claim that, contrary to Tomasello, who bases on mind reading abilities (i.e., a theory of mind), our capacity to understand others' actions and to cooperate with them, there is no need to take into account unobservable internal mental states to understand the acts of others. Mentalism is not needed, teleology is sufficient. Teleology leads us to understand behavior as intentional actions triggered by good *reasons* to act, the primary of which being goals that constitute the reasons and the end of action. The difference with the theory-of-mind approach is that goals do not have to be understood as mental states, but more simply as attractive, desirable, needed ("good" in some minimal sense, as Perner and Esken say) states of the world. For a goal being a justifying reason, it needs to be understood as inherently appealing: "without any goodness of its goal any action remains essentially irrational to us". Perner and Esken convincingly argue that we do not view our acts as provoked by internal states, but rather as justified by reasons provided by publicly accessible circumstances in our environment, and we presume that others do the same.[2] According to Perner and Esken, theory of mind relies on an over-intellectualization of our everyday explanation of others' acts because it ignores this type of *objective* reasons for acting, objective meaning publicly accessible. A teleologist is naturally inclined to cooperate because the objective desirability of goals gives everyone a reason to pursue them, their general appeal making it unnecessary to suppose shared goals in terms of embedded intentions and mind reading of others' desires. This does not mean that accessing others' mental states is never necessary when understanding their actions. Perner and Esken make clear that mentalizing becomes relevant in unusual cases, when individually different perspectives come into play as in the well-known false-belief tasks. However, in other cases, understanding others as acting for reasons does not require understanding them as mental agents.

[2] To take an example of my own (that, hopefully, Perner and Esken would agree with), I understand my neighbor's purchase of a minivan as being due to the fact that she has five children. I do not need to defer to my neighbor's beliefs or desires as theory of mind does to get such a simple explanation. The fact that everybody can understand that five children do not fit in a smaller car is sufficient.

Perner and Esken's theory is of course more articulated, complex, and convincing than this outline suggests. It constitutes a refreshing plea as it conflicts with what seems to be the mainstream tendency in developmental psychology, that is, the propensity to attribute increasingly complex cognitive processes and capacities to always younger children and now infants. Their endeavor can be seen as an attempt to (re)introduce Ockham's razor in our explanations of developmental findings and more generally human cognition, the teleological account of folk psychology creating some room for developmental changes. Such an effort toward theoretical parsimony is brilliantly illustrated by the final contribution of this first volume in which Charles Brainerd and Valerie Reyna present their Fuzzy Trace Theory.

Accounting for development over the life span: Fuzzy Trace Theory

Brainerd and Reyna (2015) open their article by recalling that the value of any theory depends on its success in fulfilling the two functions of scientific theories, which are explanation and prediction. Theories are more successful as they are able to explain a larger number of findings with a smaller set of assumptions and, more importantly, to predict findings that are unexpected and counterintuitive on the basis of competing theories and common sense. Concerning cognitive development, these explanations and predictions are expected to concern key domains of cognition such as perception, learning, memory, language, or higher reasoning over several developmental periods. This is certainly what Piaget's theory did. Brainerd and Reyna show in their article that their Fuzzy Trace Theory (FTT) is in this respect closer to Piaget's approach than most contemporary developmental theories that remain domain-specific in nature.

The strength of FTT is to provide a convincing account for findings that remain difficult to explain for both the constructivist and the information-processing approaches such as the dissociation between reasoning performance on the one hand and memory for the information on which this reasoning depends on the other, reasoning accuracy and memory accuracy being on occasion remarkably independent. FTT solves this puzzle by adopting a dual-process approach and assuming that subjects store distinct *verbatim* and *gist* traces of events. Whereas the former captures the surface form of an event and its details (e.g., exact wording, number figures), the latter captures its deeper meaning and significance for the subject. The dissociation between memory and reasoning can come from the fact that memory tasks that usually require accurate recall or recognition tap the verbatim system, while correct reasoning often involves manipulating semantic aspects of the situations and gist processing. Brainerd and Reyna explain how and why this relatively simple theory proves remarkably heuristic in predicting a series of counterintuitive phenomena and developmental reversals such as age-related increases in *false* memories from childhood to adulthood or more frequent *irrational* reasoning in adults than in adolescents. In both cases, the reversal can be explained by a greater reliance on gist with age. These findings not only are fascinating for developmental psychologists but also have profound implications for key social issues such as the admissibility of children's testimony in courtroom or the prevention of risky behavior in adolescents such as drug and alcohol consumption, unprotected sex, fighting, or reckless driving.

Apart from its capacity to predict and explain unexpected phenomena with a remarkable parsimony in basic assumptions, another strength of FTT is to account for cognitive processes at all developmental epochs. This is illustrated by the test of predictions concerning the nature of the processes governing retrieval and recognition from episodic memory in young adults. The same verbatim–gist distinction makes predictions about memory declines during late adulthood. Once more, the theory proves far reaching not only in shedding light on the underpinnings of these declines but also in predicting future diseases such as mild cognitive impairment and Alzheimer dementia better than traditional measures such as genetic tests do (e.g., the ε4 allele of the ApoE genotype).

This latter contribution closes the first volume of the special issue. As I noted at the beginning of this introduction, the second volume will gather a series of articles focusing on more domain-specific approaches to development, even if the distinction between domain-general and domain-specific mechanisms was more drawn for expository purpose than based on fundamental differences between the theories presented. In line with the contributions that the reader has in hand, the theories and models presented in the second volume illustrate how cognitive developmental psychology has evolved from the late Piagetian conceptions and the cognitive revolution of the 1960s.

Awareness and its development

The second volume opens with a presentation by Philippe Rochat (2015) of his theory of awareness development in infants and toddlers. In contrast with a common wisdom of developmental psychology from William James to Piaget, neo-nativist theories and evolutionary psychology have popularized the idea that infants are not born in a state of syncretism and complete confusion between the self, which was assumed to not exist at all at birth, and the world, that Piaget saw as a to-be-constructed category. Rochat reports fascinating findings demonstrating that even from birth, and probably before, infants differentiate between stimulations originating from their own body (e.g., self-touch) and stimulations from external sources (Rochat & Hespos, 1997). However, as he argues, this is not to say that no development occurs. His theory proposes that different layers of awareness grow from birth to the age of 5 consisting of ontologically different states of mind from non-conscious and unconscious states to awareness (the pre-conceptual and implicit state in which one is aware of being alive in a sentient body), co-awareness (to be aware of one's presence in the world with others), consciousness (the mental state in which we introspectively know of knowing through a self-reflective loop), and co-consciousness (a mental state in which we know of sharing knowledge with others). The strength of the article, and of the theory, is to illustrate by empirical facts the chronological emergence of these levels of state of mind in various domains ranging from the development of pictorial awareness, mirror self-experience, and self-consciousness, to the development of interpersonal awareness and sharing. In each of these domains, the appearance of each new level of awareness is characterized by clearly identifiable behavioral changes.

Thus far, this theory could be compared to many other stage theories describing the invariant succession of different levels of development with their specific behavioral markers. However, what makes Rochat's proposal original is the assumption that each level of subjective experience does not change or re-structure the ontogenetically anterior stages as is the case in Piaget's and neo-Piagetian theories. These qualitatively different states of mind constitute layers of awareness that are added to each other in a cumulative fashion, the mind staircase of the constructivism with its steps that children climb being replaced by an onion metaphor. According to Rochat "human consciousness consists in poly-awareness", all the levels of awareness being simultaneously present and active with various weights that change all the time, our conscious experience consisting of constantly navigating through the different layers. This attempt to capture the "polyphonic phenomenal nature of human awareness" is enthralling as it offers a way to understand this part of infants' and children's development that goes above and beyond the emergence of a rational mind and eventually sheds light on one's experience of the conscious life.

Episodic and autobiographical memory development

Among the consequences of the protracted development of consciousness described by Rochat, it has often been assumed that there is one of the most robust and popular phenomena in the memory literature, namely childhood amnesia – the fact that the average adult's earliest memory for a past event is age 3 or 4 with no memory of events having occurred during the very first years of life. In this account, childhood amnesia would be due to a lack of autonoetic consciousness, the awareness of a self extending over time that allows for a mental travel in time and the re-living of past experiences on which autobiographical memories would be based (Perner & Ruffman, 1995). In her article on the development of episodic and autobiographical memory, Patricia Bauer (2015) classifies this explanation among the traditional accounts of childhood amnesia according to which one has few memories from the first years of life because the capacity to form memories for events is slow developing and immature in young children. She notes that this type of explanation is not so far from Piaget's conception of development. Even if he did not address the question of childhood amnesia, he assumed that the first years of life were characterized by an incapacity for re-presenting objects and events, the capacity to construct and use representations only emerging with the symbolic function at the end of the second year of life. Although Bauer does not deny that the capacity to form memories probably increases with age during the first years, she argues that this positive aspect of development is only one part of the story and she invites us to consider the complementary and negative side of the mnemonic phenomena, that is, forgetting.

According to her complementary processes account, infantile and childhood amnesia emerge from opposite mechanisms, an increase in remembering but also accelerated forgetting at young ages. It is not that memories for events are not formed by young children. They are there, but disappear at a faster rate than in older children and adults, creating the so surprising distribution of episodic and autobiographical memories observed in adults. Bauer reviews a series of studies, most of them from her own lab, that demonstrate a genuine autobiographical competence even in infants when non-verbal imitation-based tasks are used. However, as she also demonstrates, memory traces exhibit a greater vulnerability to decay and interference relative to older children and adults. This is mainly due to the fact that the neural structures and networks involved in trace formation and consolidation for long-term storage undergo a protracted development. Eventually, as Bauer gracefully says, forgetting reduces the pool of memories to “isolated puddles of memories”. The complementary process account proposed by Bauer is a nice illustration of the fact that development is often a more complex process than the result of the smooth increase in the very same capacity that manifestly underpins adult competence.

Gesture as a link between action and abstraction

In her article, Susan Goldin-Meadow (2015) focuses on the role in cognition, learning, and development of gestures, the spontaneous hand movements that speakers produce when they talk. As Goldin-Meadow notes, the embodied cognition approach has popularized the idea that the body plays a central role in cognition. We could add that sensorimotor actions were also of particular importance for Piaget, who assumed that they constitute the foundation on which all the cognitive architecture is erected. However, at a first sight, focusing on gestures might sound strange as they do not produce any transformation in the world and remain most often ignored by gesturers themselves. However, in an impressive review of her work over more than 20 years, Goldin-Meadow shows that gestures not only reflect our thoughts but also are closely related to learning and can even be used to bring about changes in cognitive processes. Surprisingly, it is when there is a mismatch between gestures and the speech they accompany that they are the most revealing of the mental state of the subject and a better index of his or her readiness to learn. This has been observed by Goldin-Meadow in a variety of domains such as language acquisition, conservations, mathematical reasoning or understanding of mechanical devices in children as well as in adults. Subjects who produce gestures mismatching their speech are more prone than others to benefit from learning experiences and access a higher level of understanding. Even more surprisingly, gestures not only are reliable clues for the next transition but also can be part of this transition itself by promoting learning and transfer.

Although, as Goldin-Meadow notes, Piaget overlooked the importance of gesture in cognitive development, several aspects of Goldin-Meadow’s findings and theorizing are reminiscent of Piaget’s conceptions. For example, she explains the predictive power of gesture–speech mismatches by the cognitive instability these mismatches reveal. This cognitive instability would make the subject ready to profit from additional input, something akin to the cognitive disequilibrium that was assumed to characterize individuals in a transitional state between two stages in Piaget’s theory. At a more functional level, she assumes that gestures would promote learning by establishing sensorimotor representations that are later reactivated in further encounters with the task, and suggests that gestures provide a bridge between action and representation because they are at the same time actions and abstract representations. This can also be related to Piaget’s theorizing. It should not be forgotten that, in Piaget’s theory, representations do not result from perception (they are not a mere copy of the objects) but are internalized and delayed imitations of actions on these objects. From a Piagetian point of view, if gestures are more efficient than actions in promoting transfer as Goldin-Meadow has demonstrated, it might be because gestures are not actions but imitations of actions, and are thus more appropriate for establishing the representations on which better understanding and transfer of strategies are based. However, the parallel between Piaget’s and Goldin-Meadow’s theorizing should not be pushed too far. The theory of representations as internalized imitations in Piaget’s theory remained rather speculative and was based on informal observations such as the famous scene in which his 16-month-old daughter Lucienne opened and closed her mouth just before finding a way to open the box she had in hand, as if her action constituted some imitative representation of the action to be performed (Piaget, 1952). Moreover, the superiority of gesture (i.e., representation) over action in promoting learning and transfer is difficult to accommodate with the primary role that Piaget attributed to action in development and more generally in cognition.

Numbers as a core domain

At the beginning of this introduction, I evoked the study by Mehler and Bever (1967) on number conservation, which was among the first signs of the decline of constructivism and the advent of neonativism. Rochel Gelman (2015) perfectly illustrates this latter theoretical framework in her article about core and non-core domains in which she argues in favor of the thesis of number as one of the innate core domains of human intelligence. Interestingly, Gelman notes that she shares at least two fundamental assumptions with Piaget. With him, she thinks that concepts involve the active use of mental structures, and that these structures are systems of transformation leading to the emergence of invariants and conservations. By contrast, what is denied in Gelman's theorizing is the notion of stage as the expression of a content-free domain-general structure organizing any kind of input at a given level of development. Instead, Gelman assumes that the different domains of knowledge can be partitioned into core and non-core domains. Whereas core domains are based on innate skeletal structures, non-core domains are based on acquired structures that are learned later on in development. However, not so far from what Bjorklund assumes in his article, Gelman suggests that the incipient structures characterizing core domains serve to draw attention to a class of potentially relevant inputs, infants seeking out and assimilating these inputs that contribute in turn to the development of their innate structures. This is what Gelman calls Rational Constructivism.

Gelman reviews a series of studies providing evidence for natural numbers as a core domain of human cognition, from her seminal training studies on conservation to the classical studies on young children's compliance with counting principles and more recent studies on the existence of scalar variability in the representation of small numbers in young children. Her thesis that a non-verbal approximate number system is the source of children's and adults' understanding of both the small and large values of numbers is pitted against the popular thesis of the existence of different mechanisms for the two types of magnitudes (Carey, 2009; Feigenson et al., 2004). According to Gelman, this core domain of natural numbers and its incipient structure that allows children to master a fair amount of natural number arithmetic before entering primary school could at the same time constitute an obstacle to learning about rational numbers such as fractions or decimals, precisely because the core domain would induce a potent tendency to interpret these new symbols as a further illustration of natural numbers. The specific difficulty children encounter in mastering this non-core domain in Gelman's terms is the object of the last article of the double special issue.

Why is learning fractions and decimals so difficult?

In her distinction between core and non-core domains, Gelman states that inherent to many non-core domains is their involvement with a specialized symbol system that is difficult to learn. This is clearly the case for fractions and decimals. In a masterful and authoritative article, Lortie-Forgues, Tian and Siegler (2015) analyze the difficulties encountered by learners despite prolonged and intensive instruction, reporting facts that they rightly judge alarming about these difficulties, which affect many children but also adults, including teachers themselves. Surprisingly, one learns in reading Lortie-Forgues et al. that the problem was identified more than three decades ago, bringing about a series of educational reforms that have remained largely ineffective. For example, in 2014 as in 1978, less than 30% of U.S. 8th graders identified 2 as the best estimate of 12/13 + 7/8 among 1, 2, 19, 21, and "I don't know" as response options. Nonetheless, the mastery of fraction and decimal computation is crucial for subsequent academic and occupational success. Indeed, as the authors note, manipulating rational numbers provides children the opportunity to discover that natural numbers are only one category of numbers governed by principles that cannot necessarily be generalized to other types of numbers. For example, contrary to natural numbers, rational numbers do not have a unique successor, and the effect of arithmetic operations on these magnitudes can vary from one type of numbers to the other (e.g., the product of two natural numbers is always larger than both of the operands, whereas multiplying two fractions or decimals between 0 and 1 results in a product less than either multiplicand). Thus, numerical development goes further than the development of the innate structure postulated by Gelman to discover the properties of an expanding set of numbers from natural to rational, irrational, and eventually imaginary numbers.

However, Lortie-Forgues et al. report results convincingly demonstrating that the problem encountered by children is not simply that they mistakenly apply whole number arithmetic to fractions. In the same way, it is not simply that understanding fractions and decimals requires the formal operations described by Inhelder and Piaget (1958) and the construction of INRC structures to understand proportionality. Things are more complex, and the authors identify a series of sources of difficulties in fraction and decimal arithmetic, some of them being intrinsic to this domain, whereas others are culturally contingent and determined by cultural values and educational systems. They end their article by some encouraging findings and the description of interventions that proved effective in improving learning. They conclude that comprehensive theories of numerical development must account for the growth of rational number arithmetic and the reasons for its enduring difficulty for children and adults.

Coda

As this summary of the different contributions has probably made clear, none of the theories presented in this special issue provides the unified account of developmental changes in higher and more basic cognitive processes that Case (1985) deemed as the ultimate aspiration of any theory of development. This is probably due to the fact that the amount of findings to be explained has so dramatically increased in the last decades that such an endeavor appears nowadays unrealistic. What seems to have disappeared is the belief that there is a finite set of functional mechanisms like assimilation, accommodation, and equilibration that would account for all the developmental changes. Of course, we have seen that many mechanisms hypothesized by Piaget are still there in one form or another, such as the evolution of biological structures under environmental pressure (Bjorklund) or the role of reflection (Zelazo) and cognitive disequilibrium (Goldin-Meadow) in developmental changes. However, the traditional constructivist view with its stage-like progression through a successive integration of more and more complex structures no longer seems tenable today and key developmental changes such as those affecting awareness and consciousness seem more cumulative than integrative in nature (Rochat). It is not that constructivism is systematically denied, but it is assumed to interact in a complex way with innate structures that define potentially relevant inputs and provide us with inbuilt concepts in core domains (Carey, Zaitchik, & Bascandziev; Gelman). However, this neo-nativism itself is not immune from the risk of overinterpreting children's behavior that jeopardized many constructivist and structuralist approaches (Perner & Esken), and the possible existence of innate primitives in a given domain does not mean that children, adolescents, and even adults do not undergo almost insuperable difficulties in acquiring more complex concepts in this domain despite extensive training (Lortie-Forgues et al.). Moreover, contemporary developmental psychology makes clear that development is not necessarily the monotonic ascending function that traditional psychology described. There are striking developmental reversals due to the interplay of two different types of mental processes with their own developmental trajectory (Brainerd & Reyna), something that Piaget never envisioned, and negative changes have also to be taken into account (Bauer). Overall, unified accounts of development may have vanished, but what could appear as a regression instead is probably an enrichment, current theories of cognitive development providing us with a more multifaceted and nuanced description and explanation of developmental changes.

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