Introduction

Cognitive Development Studies: From the History of Psychology to the Current Trends in Cognitive Sciences

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The history of cognitive development studies began with the Greek philosopher Plato (Houdé, 2019)[1]. In the centre of Raphael's famous fresco, *The School of Athens* (1512) in the Vatican Museum in Rome, Italy, we see Plato (428–347 BC) and Aristotle (384–322 BC). Plato is pointing upwards to the 'Heaven of Ideas', while Aristotle, his pupil at the Academy, stretches his hand forward, symbolizing the earthly world. Indeed, for Aristotle (who does not believe in the Ideas as such), the general and the particular are transmitted here.

I.1 Step 1: The Ancient Roots of Innatism and/or Empiricism

For Plato, souls, thought of as 'immortal', have already contemplated the world of Ideas – i.e., the Good, the True, and the Beautiful – during their prenatal period. Birth disturbs this process. That is why 'the body is a tomb', according to the philosopher's expression. Nevertheless, thanks to a psychological phenomenon of *reminiscence*, triggered by the perception of concrete things in the sensible world (relations, numbers, and qualities), we can rediscover the innate Ideas. For example, Plato states that we grasp the idea of perfect equality with pieces of wood that are almost equal, but that the 'equal' itself does not reside in the pieces of wood. It is we ourselves who, from sensible objects, infer their essence. In the same way, when we look at six knucklebones, we cannot say that the number six is in any one of them, or in all of them together, since it is we ourselves who have made the connection between the Idea and the objects. Even Meno's slave, who appears in the dialogue of the same name, is able to deduce, starting from a right-angled triangle, Pythagoras's theorem: *the square of the hypotenuse is equal to the sum of the squares of the other two sides.* A century before Plato, the geometer Pythagoras (580–495 BC) had indeed demonstrated this theorem – a 'discovery of the True'.

According to Plato, these immutable Ideas are latent knowledge: they are within us from birth, without our knowing it. In this already subtle psychology, it is not a question of *ignorance* but of *latency*: dormant truths for which man seeks. It is at the cost of a mental effort, often requiring a whole education, that the innate Ideas can (re)appear. They are recalled and reactivated. Hence the importance, from a Platonic perspective, of the *maieutics* of Socrates, the art of 'giving birth to minds' (Socrates' mother was apparently a midwife), causing doubt and astonishment in one's interlocutor. Plato thus underlines the educational role of the social environment. However, learning is not a matter of filling the mind, seen as an empty *tabula rasa* ('blank slate'),

[1] Even before Socrate and Plato, there were pre-Socratic thinkers whose conceptions already looked forward to cognitive development, such as Parmenides (sixth–fifth century BC), who thought that perception was an illusion, and indeed a fraud, compared to thought.

by means of mere sensation, as it is in Aristotle, and as the young Theaetetus, an empiricist, suggests in a Socratic dialogue narrated by Plato. On the contrary, the Ideas are already present from birth, as a pre-existing cognitive store, a capital sum of reason that can be reactivated. Here we identify the ancient root of the *rationalist and innatist* trend that stretched for two millennia, right up to the 'core knowledge' of the infant cognitive psychology, according to Elizabeth S. Spelke (2000), via Descartes, Kant, Noam Chomsky (1975) and Jerry Fodor (1983).

Plato also anticipated the cerebrocentric approach: he already located the rational part of the soul (mind, intellect, reason) in the brain, whereas his pupil Aristotle, at the School of Athens, still located it in the heart (cardiocentrism). Plato, however, placed desire and its impulses in the lower abdomen, and the will in the heart. We now know that everything is in the brain (Changeux, 1985, 2012), including the mapping of desires and emotions through feelings, even though the brain's relations with the whole body are always intimate and continuous (Damasio, 1994, 2018).

Let us return to Raphael's fresco, *The School of Athens*, and Aristotle's place in it. According to Aristotle, at birth we are a *tabula rasa*. Thus, it is only within things themselves that their essence is to be found, and not in a superior Idea that transcends them.

What interests Aristotle is the discovery of *what the earthly world is made of*, the 'genera of being': quality, quantity, relation, place, time, action, etc., and their subdivisions. That is why his approach is encyclopaedic and known as 'systematic': he classifies diversity. Aristotle has thus influenced separate branches of knowledge: psychology, logic and zoology, all of which include the *logos*, implying reason and language. Aristotle distinguishes between external objects, mental images and their communication by words; but in order to understand the world and to speak correctly of it, he wishes to establish a rigorous logical reasoning that connects objects to words: a science of sciences. Therefore, he is important to philosophy, certainly, but he also prefigures the psychology of reasoning. Indeed, we owe him the discovery of the 'syllogism'.

Aristotle used logic to detect and refute the errors of reasoning, the sophisms and paralogisms, of his contemporaries in Greece (sophisms corresponds to the fake news of today, Lazer et al., 2018). Here lies the ancient root of the study of the cognitive biases of reasoning (Evans, 1989; Kahneman, 2011) and the psychological forms of syllogisms – the rules of mental logic (Braine & O'Brien, 1998) and visual-spatial models (Johnson-Laird, 2001).

A fundamental problem nevertheless remained for Aristotle: if the science of syllogisms aims at the objective knowledge of the world, how do we obtain the first true propositions, which do not themselves result from a prior deduction? Indeed, we can produce an argument whose conclusion (c) is logical (valid) but has a premise (either a or b) that is false. For example, if (a) *all men are immortal* and (b) *Socrates is a man*, then (c) *Socrates is immortal*. However, Socrates, a Greek philosopher, and the master of Plato, was mortal! How can we ensure that the initial proposals are trustworthy? This is where induction and empiricism find their place in Aristotle's theory. Not believing in the Ideas of Plato (as starting principles that are inside us without our knowledge), he appeals to a *sure and certain* faculty of recognition and judgment, which results from perception: there is no Idea without such a prior impression. Psychological empiricism is therefore inevitable. The *tabula rasa* is a corollary of the science of syllogisms.

According to Aristotle, the senses and induction lie at the origin of everything. From sensation arises memory, from memory comes experience and from *reasoned* experience (syllogism) comes the conception of the universal. It is through this inductive empirical process alone – without needing first to attain the pre-existing Ideas – that we can grasp the indemonstrable elements or axioms that are seen as trustworthy, appropriate and self-evident. From these the necessary deductions will then follow.

At birth, the intellect is similar to a tablet on which nothing is currently written, argues Aristotle in his *Peri psychès* (*On the Soul*) – arguably the first comprehensive treatise on psychology in history (just as the *Organon* was for logic). He describes in fine detail how a sensible object causes a specialized activity of the cognitive function. The latter does not receive the sensible form 'from without', but re-creates it 'from within', from its own powers, when it is affected from without. This nuanced empiricism (internal re-creation) already foreshadows the cognitive process of assimilation-accommodation described by Jean Piaget (2015; Piaget & Inhelder, 1969). According to Plato's pupil, the powers of the cognitive function come from a general breath of life, 'the soul', shared by all animate beings: plants, endowed with faculties of nourishment and growth; animals, endowed with faculties of motion and perception in addition to the preceding ones; and humans, who also benefit from the cognitive faculties of thought, of reasoning. In this way, three souls intertwined by epigenesis form a hierarchy in man: vegetative, sensitive and intellective. Human intelligence is an extension of biological adaptation, once again prefiguring the work of Piaget. The living world of Aristotle, however, is fixed: it is a *scala naturae* ('scale of beings') created by God, in which man dominates an eternal universe (like that of Socrates and Plato), not a transformist world in evolution of the kind later discovered by Buffon, Lamarck and Darwin. Unable to imagine this revolution in biology, Aristotle, as a good logician, wished to avoid an infinite regress: so, he formulated the hypothesis of a god being, the cause of all, and himself uncaused – in other words, the 'first cause'.

I.2 Step 2: The Renaissance of Innatism and/or Empiricism

According to the French philosopher René Descartes (1596–1650), men are composed of two natures: the body and the soul, the latter being specifically defined as a 'thinking substance'. He compares the body to a pipe organ, in which animal spirits act like the air between the ducts in some pipes. Body and soul may well be joined together and united by the pineal gland in the brain (the epiphysis), but only the body is a machine. This difference in nature (or substance) between the soul and the body constitutes what is called 'Cartesian dualism', which left a permanent mark on psychology: the body was the domain of physiologists and doctors, the soul was the domain of psychologists.

Descartes was an innatist, like Plato. Indeed, his thought drew on the *rationalism and innatism* of Ancient times. The Cartesian method and rules were designed to discover the Ideas and properly develop them. In Descartes, human doubt stems from an imperfection in method, whereas God is perfection. Thus, to the question 'From where do we get this precious treasure that is our intelligence?', Descartes, in his *Treatise on Man* (1664), answers with the self-evident and apparently inescapable truth: God has deposited in our minds, from birth, clear and distinct logical and mathematical ideas, the core of human intelligence. An infant is thus 'potentially intelligent' (a concept very common these days) but is intelligent thanks to God's gift. This divine explanation would be shattered by nineteenth-century biology and Darwin's description of a natural biological evolution of animal and human intelligence – excluding God from the explanation.

In the same way, the Cartesian dualism between the mind (or soul) and the body would be shattered by the neurosciences of the twentieth century – prefigured in Ancient times by the Greek physicians Herophilus and Galen – through the mechanistic study of the brain as an organ of thought, especially using brain imaging techniques. Moreover, Descartes' correlative theory of machine-animals was directly challenged by La Mettrie's *Man a Machine* (1748), which, though written in the eighteenth century, already foreshadowed contemporary artificial intelligence (the brain-machine), a branch of computer science. Finally, even though Descartes wrote a *Treatise on the Passions*, it was the dualism between the soul and the body that Damasio would denounce in *Descartes' Error* (1994), demonstrating, with the help of contemporary neuroscience and the 'somatic marker theory' that we think with our bodies and our emotions in a system of generalized equilibrium called homeostasis (Damasio & Carvalho, 2013). Damasio (2003) agreed more with Baruch Spinoza (1632–1677), who, somewhat later in the seventeenth century, came closer to modern neurobiology than had Descartes by bringing mind and body together, ascribing to the emotions a central role in human survival and culture.

After Descartes, at the Age of Enlightenment, a new and famous cognitive problem added new fuel to the debate between the advocates of innatism and empiricism: the 'Molyneux's problem', named after an Irish scholar who asked the English philosopher and physician John Locke (1632–1704) whether a man who was born blind, then grew old and was cured, would be able to distinguish by sight, without touching them, a sphere and a cube placed on a table in front of him – assuming that he had previously learned to distinguish these two objects by touch alone. Molyneux (1688 [1978]) himself believed that he would not. Locke was of the same opinion, for, according to him, visual ideas and tactile ideas were acquired independently by sense experience; and in this case, *the necessary association between the two* had not been made. It is now known that intermodal touch-vision transfer is possible at a central level in the brain, even in an infant, so the answer to Molyneux's problem is therefore 'yes' from the point of view of the contemporary psychology of cognitive development. But the problem fascinated the eighteenth century, which debated opposite points of view.

Molyneux's problem, apparently technical and limited in scope, is historically important because it corresponded to a more general key question, which aroused lively debate in the eighteenth century: what is the role of the environment and experience in the construction of our knowledge? Locke, who inaugurated the Enlightenment in England, answered this question with his empirical philosophy: knowledge results directly from the experience of the reality of the senses. Our ideas are not of divine origin (as in Descartes) but come from perception. It is out in the world that they are found; they do not lie innate within us. Otherwise, how can we explain the diversity of men, the ignorance of children, savages, idiots, and so on? Locke was a paediatrician and tutor to the children of an important politician in England, Lord Ashley; what Locke was aiming for was the *upbringing of a young English gentleman* but he also understood how each culture and each epoch has its own infancy. Hence his psychology of the child and of education, a corollary of his empiricism. Locke, like Montaigne, was struck by the weight of custom and habit, and the role of circumstances. From his observations, from his travels, from the stories he heard, he deduced that human understanding was a matter of environment, of education, and a 'reflection of nature'.

Thus, in his *Essay Concerning Human Understanding* (1690), Locke refuted Descartes' innatist psychology (and all those that had preceded it ever since Plato). Inspired rather by Aristotle, he made the human mind a *tabula rasa* on which sensations are formed during childhood, shaping ideas that associate and combine, from the simple to the complex. He defined the idea as 'whatsoever is the Object of the Understanding when a Man thinks' (a representation). According to Locke, experience can be applied either to the external objects of the environment (association between *sensation* and idea) or to the internal operations of the mind (reflection through the association of ideas). He thought that ideas couldn't be separated from consciousness. Becoming aware of ideas is an awakening of consciousness. Education to ideas is an awakening of consciousness.

In the problem of Molyneux, the man born blind possesses the conscious experience of an association between the tactile sensation and the idea of a sphere, but not between the visual sensation and the same sphere. So, nothing in his previous experience allows him to associate the two in his mind (hence Locke's negative answer). The missing mechanism, very simply, was *association*. What Locke wanted to discover, in line with the Newtonian scientific spirit and in opposition to Descartes, was a simple psychological mechanism, a functioning law that regulated the mind, the mental realm. This was the association between sensations and ideas, and the association between ideas themselves. Thus, association governed the 'world of ideas', that is, the world of psychology, like the mechanism of gravitation theorized by Newton, whose physics governed the fall of bodies and the relations between celestial bodies. Locke's work acceded to a request Newton had expressed in the *Principia* (1687): finding for the mind, as he had done for space, one, and only one, universal principle of operation.

However, this principle or mechanism of association of ideas necessarily implies a psychology of education. This is what Locke proposes in *Some Thoughts Concerning Education* (1693), in which he outlines a psychology of the child. With a clean slate as his starting point, Locke understands that the powers of the mind will demand social incentives and models if they are to develop. The *mechanism* needs to be educated, and he insists on the role of imitation and play. A properly understood education must use games that are both free and challenging, but it must reserve a place for spontaneous imitation. What fascinates Locke in children is their drive and enthusiasm, that childlike zest that bursts forth in action, play and even schoolwork. In action, as in play, this was, in his view, all an expression of *freedom*.

Locke had all it needed to be a child psychologist, but he did no more than touch on the essential problem: that of mental structures or frameworks. This was the main issue that Anglo-Saxon empiricism failed to address: beyond the mental content of knowledge (ideas), is there an active centre of the mind, a set of structures to which ideas cling? Locke came close to this when, in line with Aristotle, he described the child's powers of both feeling and reflecting. However, he said nothing about how these sentient and cognitive powers are structured (or structure themselves) in the mind. Returning to Descartes' innatism, Emmanuel Kant (1724–1804) will say that these powers were already in existence: for him, they were an *a priori* of understanding.

Following on from Locke, David Hume (1711–1776), a Scottish philosopher who was an acquaintance of Rousseau, completed the project of empiricism in the same scientific, mechanistic and Newtonian spirit. He insisted on our faculty of *imagination* that worked on the basis of sensations: we *imagine* ideas, which involves a certain margin of uncertainty. In order to understand how the very powerful human imagination associates ideas with each other on the basis of experience by bonding them together (by 'attraction' as Newton would have put it), Hume described more precisely than Locke three sub-processes: (a) the spatial or temporal *contiguity* of objects in reality, a contiguity which configures our memory and the mental evocation of ideas; (b) the *resemblance* of each copy to the general idea; (c) the *cause and effect relationship* that underpins our belief system and our practical knowledge.

According to Hume, these processes of 'assembly' can operate incredibly fast in the human mind. His empiricism was original, very cognitive in nature (memory, beliefs, etc.) and even prefigured Daniel Kahneman's *system 1* today (Kahneman, 2011).

In France, Étienne Bonnot de Condillac (1714–1780) formulated a so-called sensualist version of Anglo-Saxon empiricism in his *Essay on the Origin of Human Knowledge* (1746): all our understanding, from perception to judgment, is *and must be* derived wholly from sensations. This means that we need to reform and purify our language so that it will organize sensations in such a way as to impose a precise correlation between words and things. That is what Condillac, a member of the French Academy, advocated to the scholars and philosophers of his time: they needed to express their knowledge in a correct, pure, clear language so that everyone would be able to grasp that knowledge. This was also the aim of Diderot in the *Encyclopédie*. Condillac wrote his *Grammar*, *The Art of Writing*, *The Art of Thinking*, *The Art of Reasoning*, and so on with this aim. In his main work, *The Treatise on Sensations* (1754), he explained that the understanding was like an inert 'statue' that resided within us before existing in the outside world; contact with the world through the senses gave this statue life in the following order: smell, hearing, taste, sight, touch. The ideas derived from these five senses were simply sensations designated by words that represented things. These sensations developed and combined, thereby shaping the understanding. However, this still leaves the problem of the mysterious inert statue from which it all began!

From Locke to Condillac, empiricism assumed various different forms in order to promote the same general psychology that marked a revolt against the Cartesian *cogito*: for the empiricists, the environment shaped reason. Nevertheless, the question of the powers of the understanding touched on by Locke in his psychology of the child, and the 'inert statue' within us in Condillac, reveals the difficulty empiricism encounters in giving an account of the frameworks of the mind, which can structure and perhaps even precede the experience of sensations. Without this, the associations of ideas by the empirical connections of contiguity, resemblance, or cause and effect, as in Hume, remain contingent, 'scattered around' by circumstances without any real active centre (self, or *cogito*, in Descartes' phrase). This is where Leibniz, Wolff and Kant contributed to the debate.

The German mathematician Gottfried Leibniz (1646–1716) refuted Locke's thesis on the non-innate nature of ideas point by point. His critique promoted the view that there are Ideas that exist *independently of us*. According to Leibniz, the understanding is innate and allows us to process the data from experience through 'necessary ideas': that is why he gives the answer 'yes' to Molyneux's problem. By definition, these ideas are not contingent; that is, they do not depend on environmental circumstances, contrary to what the empiricists believed. Moreover, Leibniz observes that when the understanding, endowed with its necessary ideas (the self, the *cogito*), meets the perceptual world, representations emerge, which are not always very clear, mixed with an infinity of 'little perceptions' that can confuse consciousness and reflection and sometimes even elude them altogether. This view was still quite different from that of Locke, who supposed that ideas derived from the senses could not be separated from consciousness. In the end, one has the impression that, for Leibniz, the role of the environment was not positive or, at least, not as able to structure mental life as the empiricists seemed to suggest.

A pupil of Leibniz, Christian Wolff (1678–1754), then published a two-part treatise on psychology *Psychologia empirica* (1732) and *Psychologia rationalis* (1734) that forged a remarkable methodological synthesis, paving the way for Kant. As these titles indicate, Wolff distinguishes between two types of psychology. One is *empirical*: it needs to be based on external or internal observation, through introspection, and to lay bare the laws of human conduct and the faculties of the soul by measurement and calculation, like in physics. Wolff called this very prophetically 'psychometry', heralding Fechner's psychophysics in the next century. The other psychology is *rational* and belongs to pure reason: it enables us to determine *a priori*, by reasoning, as in algebra or geometry, what the faculties of the soul must be. Wolff advocates combining these two psychologies; the second kind is also able to feed on data known *a posteriori*. Thus, almost all-future psychology found itself already defined.

After Leibniz and Wolff, their disciple Kant formulated propositions that are still current in today's psychology, in line with a tradition that went back to Plato via Descartes. He said that pure concepts exist in us innately, as mental frameworks or 'categories of the understanding'; these do not come from the sensible world (the environment of the empiricists). Kant, following Wolff, gives the name 'pure reason' to so-called transcendental, metaphysical knowledge, superior to and outside of the world. This exists *a priori*, independently of our sensations. These *necessary and universal* cognitive principles relating to space, time, number, etc., are in us from birth, but only sensible experience, from infancy to adulthood, can *reveal them*. Thus, according to Kant, reason neither alone (rationalism) nor sensations alone (empiricism) make it possible to know the world. The intermediary here is the 'schema', which links pure, innate concepts with *intuitions*, for example intuitions of space, time, number, etc. that are linked to sensible experience and its representations. Thus, the schemas, or frameworks, of the mind allow us to make judgments about reality. This notion of a schema (or scheme) would be made famous in the twentieth century by Piaget, who made it the basic unit in his constructivist (non-innatist) theory of intelligence in the child. Other current programmes in the non-Piagetian cognitive sciences are more innatist and follow Kant in considering the possibility of *a priori* mental frameworks which sensible experience reveals from infancy to adulthood. This is the case with Dehaene and Brannon's (2010) view: 'Space, Time, and Number: A Kantian Research Program'.

The path travelled since the Renaissance shows that the history of psychology has been punctuated by a cognitive reform. In the seventeenth century, cognitive reform began with Descartes, the discoverer of the *cogito*, and Pascal, the critic of reason, who promoted *finesse* against *geometry*; but he was still reckoning without a mechanistic science (that of Copernicus, Galileo and Newton) that had not yet affected psychology. We had to wait for empiricists like Locke and Hume *to move on from the laws of space to those of the mind*. Like nature, the mind itself could now be something to be observed, analysed and understood from an external scientific perspective. The new explanation, however, still lacked 'frameworks', and Kant restored them: pure concepts and innatism, *schemas for sensible experience*. Kant thus saw rationalism and empiricism as two sides of the same coin. While his approach was metaphysical, the repercussions of the *a priori* on psychology were still great, forming a kind of tradition leading from Plato to Descartes and then on to the innatism of the current cognitive sciences.

I.3 Step 3: From Innatism/Empiricism Duality to Jean Piaget's Constructivism

In the nineteenth century, the English naturalist Charles Darwin (1809–1882), in *The Origin of Species* (1859), formulated the hypothesis – now accepted – of a general mechanism of *natural selection* that applies to *populations* and is based on a two-fold principle. The first principle is the *variation* of characteristics, generation after generation (the genetic origin of this random variation would be understood only after Darwin, thanks to Mendel's laws). The second principle is the *selection* by survival and reproduction of those who have (by chance) the combination of characteristics best suited to their environment. The effect of the environment is therefore indirect, and there is no longer, as in Lamarck, a heredity of acquired characteristics (by daily habit). To this, Darwin adds a world-shattering new idea: *all* living things have a common ancestry, because life on earth has a unique origin, from bacteria and blue algae to man!

Thus Darwin introduced into science and psychology the idea of a *natural* evolution of animal and human intelligence or cognition through *phylogenesis* or the evolution of species, a process lasting millions of years, in which matter, life and thought are intertwined – thus excluding God from scientific explanation (and, by the same token, ruling out the divine-innate ideas of Descartes and Plato). In *The Expression of Emotions in Man and Animals* (1872), Darwin described in detail studies of the expressions on the face and the emergence of language in children. The baby he observed was his own son, Doddy Darwin. This was the century of the first monographs devoted to children: the French historian Hippolyte Taine (1828–1893) and the English physiologist William Preyer (1841–1897) both reported observations taken from their own children. The Americans Stanley Hall and Arnold Gesell would later develop methods that are more systematic.

In the twentieth century, this idea of an evolution of intelligence was taken up again in the study of *ontogeny* – the idea that, from infancy to adulthood, body and mind evolve. The Swiss Jean Piaget (1896–1980) developed this in the psychology of the child's cognitive development and the French Changeux in neurobiology (his 'neural-mental Darwinism'). According to the latter theory, Darwin's variation–selection mechanisms also operate in the brain itself, affecting cognitive representations within *neuronal populations* – a theory that Changeux (1983, 2012) shares with the American Nobel Laureate in Physiology or Medicine Gerald Edelman (1929–2014). In fact, all scientific psychology has to consider two timescales: *phylogenesis*, or the evolution of species (Darwin), and *ontogenesis*, that is, development from infant to adult (including embryogenesis). In addition, there is a cognitive 'microgenesis', which corresponds to the much shorter time taken up by learning or by the brain when solving a task: months, days, hours, minutes, fractions of seconds, i.e., milliseconds.

In the twentieth century, the most dominant figure in the study of cognitive development was Piaget. His very new approach was the basis of genetic (in the sense of *ontogenesis*, not genomic) psychology and epistemology. Piaget's contribution to the history of psychology and ideas in general was to produce a real synthesis between empiricism (from Aristotle to Locke and Hume) and innatism (from Plato to Descartes and Kant). He rejected both trends as too simplistic and proposed a third intermediate way: *constructivism*. In his experimental and clinical studies involving children, he demonstrated the construction of psychological structures, from the stage of sensorimotor *schemes* (as in Kant) in the infant to the stages of concrete operations in the child and then the formal (abstract) operations in the adolescent. This comprised the genesis of logico-mathematical intelligence, from intuitive and illogical levels in infants and preschool children to the logical levels in school children and adolescents, a view now revised by post-Piaget thinkers. Others supplemented it by focusing on the more emotional, social and cultural origins of human cognition: namely the Russian psychologist Lev Vygotski (1896–1934), opening the way to the American psychologists Jerome Bruner (1915–2016) and Michael Tomasello (b. 1950).

Challenging both the empiricism of Locke, Hume and Condillac, who believed everything derives from experience through association and practice, and innatism (the opposing theory), which explains everything through innate structures (see Plato and Descartes, but also Kant and his *a priori* forms of sensitivity), Piaget proposed an intermediate theory, called 'constructivism'. It holds that intellectual structures, i.e. our thoughts, our mental operations, have a genesis specific to them (cognitive ontogenesis). From birth to adulthood, they are gradually *constructed*, stage by stage (like going upstairs one-step at a time), in the context of the interaction between an individual and his or her environment – or, in more biological terms, between a body and its environment. In this interaction, what is essential for Piaget, is the *action* of a child on objects that surround it (exploring, handling and 'experimentation'), a concept very different from the idea of 'passive' learning (association and practice) specific to empiricism.

I.4 Step 4: Neo- and Neuro-constructivism in Cognitive Sciences

The purpose of this *Cambridge Handbook of Cognitive Development* is to provide comprehensive and detailed work on cognitive and brain development, since the seminal work of Piaget. That is for 40 years (1980–2020).

During the last decades, detailed behavioural studies have shown that Piaget underestimated the cognitive and logical (even scientific) capabilities of infants, as shown by the American psychologists Renée Baillargeon, Alison Gopnik, Elisabeth Spelke and Karen Wynn for example (Gopnik, 1999, 2012). Conversely, Piaget overestimated the cognitive capabilities of adolescents and adults, which are often biased by illogical intuitions and overlearned strategies (or heuristics) they fail to inhibit, as shown by the Israeli-American psychologist Daniel Kahneman (2011), Nobel laureate in Economic sciences in 2002 – and other authors, namely the British Jonathan Evans (1989, 2003).

Therefore, cognitive developmental psychologists are now facing a big paradox: the early smart skills of infants and the late illogical ones of older children and even adults. The new challenge is therefore to account not only for an incremental stage-by-stage process like in Piaget's approach, but also for a non-linear dynamical system of growth (Siegler, 1996). Within such a system, competing strategies, i.e., intuitive ones (heuristics) and logical ones (exact algorithms), may occur in the developing brain with different weights at any point in time, depending on the context and individual differences. This dynamical modelling introduces less regular developmental curves containing perturbations, bursts and collapses. Often, in some contexts, children fail to inhibit misleading heuristics (Borst & Houdé, 2014; Houdé, 2019), which explains these developmental irregularities, formerly called horizontal and vertical 'décalages' by Piaget ('only to save face', because it was a very strong objection to his incremental and structuralist theory). In fact, 'décalages' are not the exception, as Piaget thought, but the rule!

The current non-linear and dynamical approach better matches with the complexity of cognitive development that all the parents and teachers watch every day. It also points to the brain attentional and cognitive-control mechanisms as the key factors of development.

The general aim of the handbook is to present, illustrate and summarise this new epistemology of cognitive and brain development that we call 'neo- and neuro-constructivism' (in line with Mareschal & Johnson, 2007). 'Neuro' because of, after Piaget's time, the development of brain imaging techniques and their use in experimental psychology conducted to study both brain construction and cognitive development. Within this co-construction, we must also now consider the multiple mechanisms by which genes may influence behaviour, having in mind, as Changeux states in this book (Chapter 2), that:

> the human brain is, neither John Locke's blank slate (*tabula rasa*) deprived of any pre-existing innate structure – or, in a modern language, a random network of undifferentiated neurons fully instructed by experience – nor a fully genetically determined, irrevocably hard-wired neuronal architecture . . . It is a unique compromise between an eminently variable, intrinsically rich, connectivity and a set of species-specific, genetically determinated, rules, which unambiguously make our brain that of *Homo sapiens*.

To achieve this general 'neo- and neuro-constructivism' aim, we have invited current leading scholars from neurobiology, developmental cognitive neuroscience, experimental child psychology and computational modelling.

I.5 Overview of the Handbook Contents

An opening section (Part I) covers the neurobiological constraints and laws of cognitive development: *how the brain constructs cognition.* Damasio and Damasio (Chapter 1) describe and explain how life regulation and feelings motivate the cultural mind, from the dawn of life to humans today, through *phylogenesis*. Then, in Chapter 2, Changeux explores the key principles of *epigenesis*, synapse selection, cultural imprints and human brain development, from molecules to cognition. Chapter 3, by Cachia, Mangin and Dubois, presents the current mapping of the human brain from the preterm period to infancy using 3D magnetic resonance imaging (MRI). Next, Chapter 4, by Paus, continues this description by the human brain development and maturation processes from infancy to adolescence. Then, Posner and Rothbart (Chapter 5) add an important focus on genetic and experiential factors in brain development using the examples of executive attention and self-regulation. Finally, Luna et al. ends this Part I developmental description by the brain basis, underlying the transition from adolescence to adulthood in Chapter 6.

The following section (Part II) covers the fundamentals of cognitive development, from infancy to adolescence and young adulthood. A first subsection covers the roots of thinking in infancy. It starts with Vauclair's description