UNDERSTANDING COGNITIVE DEVELOPMENT

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CHAPTER 1

INTRODUCTION: STUDYING HOW THE MIND GROWS

It is often said that the human brain is the most complex object in the universe. This refers to the billions of neural connections and their extraordinary organisational structure. But what gives us even more pause for thought is what seems to be contained within that relatively small organ. For not only does it enable superb feats of motor dexterity and incredible adaptations to the demands of a challenging physical world, it *contains* that world in the form of conscious knowledge. If we include that which we have accumulated through scientific advance, it is not an exaggeration to say that in this tiny little speck of cosmic matter, we have in effect internalised the cosmos itself – to its furthest known reaches in space and time.

This is because we have minds, not just brains. We have the ability to represent the space in which we live: to perceive, predict, remember, talk and reason about it. This book concerns the first decade of life, at the end of which all of these abilities will be approaching adult levels. To follow the journey the child takes from helpless infancy to mastery of its own particular universe, we will be considering the main driving forces of this growth and how they interact. We will start with elementary perceptual and motor abilities and how these combine to give the child increasing control over its personal and interpersonal space. We will trace the way in which a natural desire to interact, share and communicate with others becomes grafted onto the tools for making this possible – speech and language. Perception, memory and language all grow and combine to let the child make predictions about time, space, objects and people, eventually leading to logical reasoning and the ability to think beyond the self and into a more objective reality.

How do we know all this? As you may be aware, there have been various theories of cognitive development, each leaving its mark in terms of experimental discoveries and its methods of investigation. The methodologies you will encounter in this book range from simply charting the natural patterns of skill acquisition to more contrived experimental situations aimed at narrowing down the important factors involved in acquiring a particular ability. You will also sometimes come across attempts to specifically train children on certain skills. This book tells the narrative of what has been uncovered about the growing mind of the child – whatever the methods and general approach motivating the discoveries. You will see that, despite the many and sometimes disparate theoretical leanings behind all this research, a remarkable cohesion emerges as the story progresses. In some ways to understand cognitive development you simply have to know and consider what develops, when and how. It tells its own story.

Before we start, however, it is important for you, the student, to be aware of some of the broader 'theories' of development, to know at least a little about those who have tried to impose an over-arching theory on the development of cognition, and the methodologies that emerged from them. In this brief introduction, we will consider some of these.

PIAGET: HIS IMPORTANCE AND HIS CRITICS

You may have heard of Piaget, the Swiss psychologist and philosopher (1896–1980), and may even be familiar with his phases and stages of development, but do you know why he has been such a hugely influential figure in psychology? You could refer to his prolific output in terms of detailed research monographs covering topics ranging from children's understanding of time and space (Piaget & Inhelder, 1967; Piaget, 1969) to their comprehension of the nature of life (Piaget, 1973). But the main reason Piaget was so exceptional is because of the *question he asked*, which was 'where does knowledge come from?' By this he did not usually mean knowledge gained directly through our senses or passed on by repute (such as 'Italy is a country in the Mediterranean'). He centrally and enduringly wanted to know about the kind of knowledge we would call logical or mathematical. For example, how do we come to know that it is necessarily true that if $A = B$ and $B = C$ that $A = C$, or that $2 + 2 = 4$ necessarily implies its converse: $4 - 2 = 2$? Of course it is true that logical and mathematical truths have been 'discovered' by logicians, and mathematicians such as Plato, Aristotle and Euclid. But many philosophers, even today, would consider these as truths that somehow exist independently of us and 'in the world'. Piaget's audacious idea was that they are constructs of the human mind.

This is why Piaget turned his attention to child development. Aware that mathematics and logic are constantly evolving disciplines, he believed that each new discovery or system of logic is the product of a private intellectual achievement that we are all capable of. So if logic is not a 'given', how are we to discover how it is 'constructed' from personal experience? This is what Piaget says:

> In contemporary man, an enormous number of structures have already been formed, and we don't know their history. It's a concept that has been collectively elaborated over an enormous number of generations. You don't grasp the mode of construction in these cases, you get the products. Products aren't enough for me! Thus reconstructing history – it can be done as far back as the Greeks, but even then … *What is wonderful about the child is that you have an individual starting from scratch, and you can see how all this occurs.* (Bringuier, 1980: 20)

This quotation tells you why Piaget studied children. It is also why his approach is called **genetic epistemology** (the growth of knowledge). Also notice the word 'structures'. If you have studied Philosophy, you will know that **Structuralism** was a general theoretical movement that influenced many disciplines from Linguistics to Sociology. In line with this movement, Piaget thought of the mind as the instrument by which logical structure is created. Influenced by contemporary French and Swiss mathematicians, he conceptualised logic in terms of a connected system of **operations.** These were called the INRC group, meaning Identity, Negation, Reciprocity and Correlation. You can think of three of these as ways of making a simple logical change (Identity means no change). Let's take Negation; an example would be converting +3 to –3, and what was important for Piaget is that this operation is reversible such that by negating –3 you get back to +3. An example of a reciprocal operation would be to turn the proposition A is bigger than B (A > B), into B is smaller than A (B < A) – another reversible operation. Correlation refers to using negation and reciprocity together, so here we might say A > B is negated into A < B and so by correlation B > A. The main idea to get from this is the fact that the operations work as a system or a structure.

A biologist by training, Piaget's second adventurous idea was that there is a kind of 'biology of knowledge' (Piaget, 1971) in which logical structures represent a way of keeping the psychological world in a balanced state or **equilibrium** in much the same way that hunger, thirst and thermo-regulation operate. Piaget thus adopted words that normally apply to biological functioning like **assimilation** (similar to e.g. eating) and **accommodation** (this might be adjusting the muscles in relation to external pressure). By a constant cycle of feedback from taking in and adapting to the external world, Piaget thought the child would learn to predict it in ways that are evident in **action schemas** (or sometimes, **schemata**). These are repeatable stable behaviours that work for the time being, until the child's system is ready and open to take in a bit more information – to reach a new structural level if you like. A simple example is a baby throwing its toy over the edge of the pram repeatedly, and then suddenly elaborating this schema to now include the behaviour of visually tracking its disappearance by looking over the edge. This is the beginning of what is known as the **object concept** and we will be picking up on this in Chapter 4. The gradual expansion of these behavioural schemas is what is known as the **Sensorimotor Phase** of development that Piaget thought to last until about 18 months. If you now put this idea together with the structural one, you may understand why so many of Piaget's tasks were about the transformational structure of physical situations.

Piaget's third big audacious idea is perhaps the hardest to grasp, but it is the key to why he famously argued that development should be divided into four main phases. He believed that these sensorimotor adaptations to the physical world are actually an expression of the logical operations mentioned above. Operations, in other words, start out as the transformations that are carried out at the level of actual behaviour. These can produce reversible consequences like moving an object from place A to B and back again. He believed that the origin of logic is actually *in* the actions carried out on the world. Thus at the very heart of Piaget's theory is the idea that mental development is due to the **internalisation of action**. His proposed second main developmental

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phase – **Pre-operational** – refers to the fact that, with the growth of symbolisation, such as play and imitation, and through their language, children become able to mentally represent these transformations. However, he argued that the pre-operational phase (as its name implies) is characterised by children's thoughts failing to achieve the mental equilibrium that is the hallmark of a true operational structure. They can, in other words, internalise and represent certain transformations but not their logical interconnections. This is perhaps most famously illustrated by his **conservation tasks**, such as the conservation of liquid and numeric amounts as depicted in Panel 1.1. Young Children cannot represent the reversibility in these physical transformations of state as illustrated by the two four year olds here. Piaget used a method of detailed verbal questioning with children to try to understand their mental processes during the gradual emergence of operational thought. When they *start* to think in terms of logical structures (the **Concrete Operational Phase**) their answers show that they can now grasp that the relations 'taller than' and 'wider than' must be correlated – an increase in width is compensated for by a decrease in height, and vice versa – and they will refer to this in some way when justifying their answers. How does this new insight come about? According to Piaget, it is through specific concrete experiences with physical changes such as these that children learn the elements of logical rules, and how to co-ordinate them within a system. The start of the **Formal Operational Phase** marks the point when these rules are themselves represented. So from around the age of 11 or so, the child can now (he argued) represent an in-principle logical relationship in the absence of a concrete example, such as 'A is bigger than B: B is bigger than C; therefore A is bigger than C'. One of the operations involved here is the transformation of 'A is bigger than B' to 'B is smaller than A', allowing the formation of the logical series A > B > C, and the conclusion that A must be bigger than C. This is called a **hypothetico-deductive** inference and we shall be returning to it in Chapter 16.

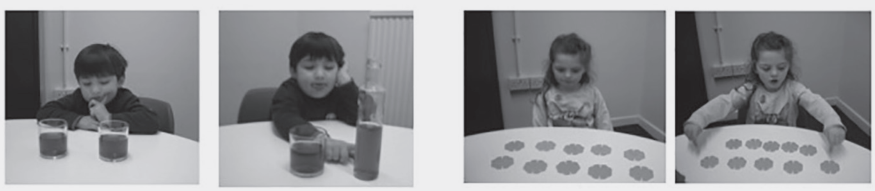
If you are interested in following Piaget's ideas further, you should try to read the work by the man himself (in translation). One short and relatively easy summary of his position is his book *The Child and Reality* (Piaget, 1972).

So why is Piagetian theory now part of psychology's history rather than its present? Why do we not still talk about operations and INRC groups and so on? The fundamental reason was that the logical model was too restricted and too rigid to have general applicability. It curiously both under-estimated children's logical abilities as well as overestimating them. As for the first, the **Neo-Piagetian** approach refers to research by the many independent developmentalists who studied Piaget's tasks (including conversation) and found that children could solve them earlier than Piaget claimed. This was, however, only if certain changes were made. These drew attention, for example, to the salient bits of the task (McGarrigle & Donaldson, 1974), changed the wording to reduce confusion (Rose & Blank, 1974), or to make the point of the task more obvious (McGarrigle et al., 1978). Sometimes simple training was used to achieve improved performance (e.g. Pasnak et al., 1987). These were all important bits of research – maybe less because of the (sometimes a bit repetitive) claim that Piaget had got the 'age' of reasoning wrong, but rather because they drew attention to the fact that logic is not grasped as a totality, but is gradual and piecemeal and very dependent on numerous psychological factors.

Panel 1.1 The influence of Jean Piaget (1896–1980)

The profound and provocative theory of the Swiss developmental psychologist, Jean Piaget, was based on a search for the origins and growth of logical thought. His massive output covered sensorimotor development in infancy through to adolescent reasoning skills. Believing logical thought to derive from the gradual internalisation and mental co-ordination of actions performed in the real world, Piaget's task typically involved physical transformations in space.

For example, his very famous conservation tasks demonstrated that young children may understand physical relationships without being able to connect them within a logical system. Pre-operational children (below the age of around 6 years old) would typically fail to co-ordinate the width of a vessel with its height or the spacing (density) of a row of counters with its extent. They would therefore not understand that transforming two visually identical amounts by pouring liquid from a small wide glass into a taller, narrower glass, or by spreading out one of two rows of counters does not affect their equivalence (see figure below). One of the most famous 'wrong' answers in developmental psychology is 'this one has more'.



Four year olds performing conservation tasks

Piaget's tasks have been successfully replicated over subsequent decades but his findings have been considerably re-interpreted in the light of changes to the tasks and new approaches that do not view cognitive development within the very restricted context of logical thought.

Piaget was nevertheless regarded as one of the great thinkers of the twentieth century and he remains, to this day, the greatest influence on how to study the growth of mind.

In fact, as researchers became progressively detached from trying either confirm or disconfirm Piaget's claims, an alternative picture of logical development started to emerge. This essentially showed that the psychological factors such as language understanding, memory and world knowledge are the very basis on which reasoning and inference grow and this remains true into adulthood. Psychological research was increasingly indicating that Piaget's emphasis on logical structure did not really capture the essence of human cognitive development. We shall be considering examples

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of these more psychological interpretations of children's reasoning in Chapters 13, 14 and 15. In short, Piaget's logicomathematical model failed to be applicable to everyday reasoning skills, because cognitive development is not centrally about the grasp of logical structure. However, children do become capable of relatively abstract reasoning as we shall see in the final chapter. Likewise mathematics does of course feature as part of the child's learning. In the last chapter we shall consider the cognitive demands this makes on children as they start to reconcile their 'natural' modes of thinking with the more formal structural properties of the number system that most children will acquire at school.

NEO-NATIVISM

One of the more dramatic reactions to Piaget was with regard to his account of the slow emergence of skills during the sensorimotor phase, and his argument that this complex cycle of schema development arose very gradually from a few simple reflexes. He strongly believed in biological maturation as well as the role of practical experience, but his position (called **interactionist** or **constructivist**) was based neither on pure learning nor genetic pre-programming. Given the rise in interest in genetics during the 1970s, there was a something of an outcry that Piaget accorded the infant with so little by the way of ready-made skills. Equipped with new methodologies, the **neo-nativists** were researchers that re-considered and re-investigated very early infancy. Amongst these were Tom Bower at Edinburgh University, Liz Spelke at Harvard and Renee Baillargeon at the University of Illinois. In the main, this movement resulted in rather strong claims about the capabilities of very young babies that have been somewhat modified since by improved knowledge of what the infant brain is (and isn't) capable of. This wave of research has nevertheless introduced a vast new body of work on early perceptual sills, and we will be reviewing what has been learned from it in Chapters 2 to 4.

Strong claims about 'innateness' are also associated with very pronounced and somewhat controversial views on the nature of human language, spawned by the work of linguist Noam Chomsky, in his ground-breaking book *Syntactic Structures* (1957), arguing for the innateness and thus universality of grammar. This was not based on a criticism of Piaget, but rather the Behaviourist movement with its focus on learning from experience, but it helped to bolster the general nativist trend. It also served as a reminder that Piaget had been rather quiet on the important subject of language acquisition and communication. What we know now about this topic – partly as a result of the 'Chomsky' debate – has more than made up for Piaget's shortcomings and we shall be covering this topic in Chapters 5 to 9.

DOMAIN-SPECIFICITY AND R-R THEORY

Another overt criticism of Piaget was with regard to his one-size-fits-all concept of operationality, which became known as a **domain-general** approach. Around the time that the famous cognitive psychologist and linguist, Jerry Fodor, published a book describing the mind as made up of 'modules' each designed to carry out its own special function (Fodor, 1983), similar arguments were applied to developmental psychology (see Hirschfeld & Gelman, 1994 for a review). Annette Karmiloff-Smith, amongst others, promoted a new approach emphasising the **domain-specific** ways in which perceptual, linguistic, numerical and other skills emerge, but each from their own different innate blueprints and therefore not necessarily all at the same rate (Karmiloff-Smith, 1992). In this way, she was able to endorse a nativist approach whilst also maintaining Piaget's constructivist ideas about how knowledge grows within those domains. Her resolution of the Piagetian domain-generality problem was therefore to posit a common mechanism that could drive cognitive change but in different ways depending on the domain. This she called **representational redescription** (R-R). This resonated with other theories of cognitive development drawing specific attention to increasing levels of conscious awareness and 'abstraction' of knowledge as children get older (e.g. Werner, 1948; Kendler, 1995). Karmiloff-Smith specifically proposed that 'implicit' knowledge during early development becomes accessible in increasingly explicit formats.

Here is an example. As you will learn in Chapter 7, children learn very early that the little word 'a' (the indefinite article) performs a different function from the word 'the' in which one and only one of a set of things is being identified. However, in French the indefinite article ('une') can also refer to 'one'. Karmiloff-Smith (1979) identified a backwards progression in French-speaking children where they started to use the French version of 'une' as if it meant one and only object rather than one of many and she argued that the understanding that the article can perform two different functions – une meaning 'one' and une meaning 'a' – was becoming *explicit* knowledge in the child's mind and interfering with what they carried out at an *implicit* level earlier. Karmiloff-Smith (1992) gives other examples from different domains of knowledge such as physics, mathematics and so on, and R-R theory has continued to be successfully applied to accounts of spelling, grammar and drawing, amongst other things (Cheung & Wong, 2011; Critten et al., 2013). It has even been found useful in considering the nature of consciousness itself (Timmermans et al., 2010).

However, there is still some debate as to how implicit knowledge becomes 'accessible' (Lin & Zhou, 2005) and indeed there are cogent arguments that some highly explicit understanding, underwriting skills, such as driving a car, actually become automatic with practice and much *less* accessible to conscious awareness (Shiffrin & Schneider, 1977). This argument has even been applied to the early development of infants in terms of how they quickly learn to negotiate movements in physical space (Diamond, 2006).

But whilst a great deal of cognition either becomes or remains inaccessible to conscious awareness, it does seem to be conscious explicit knowledge that is subject to most developmental change after infancy and it therefore represents a large part of the content of this book. We shall be returning to the implicit/explicit distinction in Chapter 11.

SOCIO-CULTURALISM

An entirely different reaction to Piaget's views came from the observation that he paid very little attention to the influence of adult culture on the child's development. This does not mean he was insensitive to its importance or to the effects of cultural variation across different countries and even across different historical epochs – he often noted that formal structures are 'linked' to their cultural evolution. But Piaget's account is essentially about the universal child interacting alone and 'privately' with his or her physical environment. An extraordinary antidote to this rather skewed view came from the work of Soviet psychologist, Lev Semenovich Vygotsky (1896–1934). Born in the same year as Piaget, Vygotsky only carried out about 10 years of research with children until his early death. So why the massive impact of this still very famous and much-cited psychologist? In fact, the impact wasn't felt in the West until the mid 1960s after the publication of a translation of collected works by Vygostky (Vygotsky, 1962) and promoted strongly by a very influential and articulate American psychologist called Jerome Bruner. Vygotsky's views supported the Marxist–Leninist position predominant in the Soviet Union at his time of writing, which emphasised the role of society in shaping individual behaviour through language in particular. So, for example, mental concepts, such as 'flower' or 'dog' were thought to be acquired by a process of shaping whereby the language of the adult gradually 'guides' the child towards the precise attributes that belong exclusively to that class. This process of social tuition through language was argued by Vygotsky to produce an internalisation of language into something he called **inner speech**, which starts to have an enabling role in thinking and problem solving. Although there was a famous disagreement between Piaget and Vygotsky over this (by letter – they never met), they ended up with a reconciliation and high mutual regard. We will be considering the development of classification in Chapter 13 and you will see how both Piaget and Vygotsky were indeed both correct – it is the external forces of language and adult tuition working alongside some universal cognitive constraints on understanding that let the child acquire 'adult-like' concepts. Vygotsky's emphasis on the role of adult culture on the child's development did much to redress the balance towards considering the social and linguistic factors involved in cognitive development, and it is not surprising that Vygotsky had, and continues to have, a major impact on educational theory. The role of inner speech, or talking to oneself, has always been notoriously difficult to measure, but has again become a topic of considerable interest since the development of brain imaging technology opened up new possibilities of determining more precisely how it may be related to other cognitive processes (see Fernyhough & Alderson-Day, 2014, for a review).

INFORMATION PROCESSING APPROACHES

When trying to understand cognitive development, it is important to distinguish between characterising how it progresses and accounts and trying to explain *why* it progresses. For Piaget, the main causal driving force is a kind of adaptation similar to the environmental adaptations that cause new species to emerge through evolution. The maturing brain, he argued, is itself affected by these adaptations (an idea very much in line with contemporary views of brain development). And all accounts that put some emphasis on learning through experience (such as the R-R theory) are similar in that regard. Some, however, place a greater emphasis on biological maturation as a cause in itself, and for them cognitive growth might seen to progress almost autonomously because of an increase in brain power – rather like having your computer regularly upgraded for a more powerful one. Explanations of cognitive development using this computing metaphor often go under the name of **information processing** theories. These have been used to explain developmental changes on problem-solving tasks, including Piagetian ones, as well as on standard memory tasks. These approaches are particularly associated with researchers (based in Canada, the USA and Australia) such as Juan Pascual-Leone, Robbie Case and Graeme Halford. As the name implies, the emphasis is on how much information a child at a given age can process, and it draws on concepts deriving from classical memory research, such as short- and long-term memory, storage capacity, speed of processing and attentional mechanisms. By measuring such things during cognitive tasks, this type of approach has yielded valuable information on how speed and efficiency of processing information increases with age (Kail, 1991). However, memory 'processes' are not independent of familiarity and knowledge of the material to be remembered (Chi, 1978), and, as you will see, there is only limited predictability of developmental change arising from pure processing concepts alone. The content of a child's knowledge (and the basis for their reasoning) is founded primarily on things like the 'who', 'what', 'where' and 'when' of people, objects and events in their lives, and we shall be considering memory process in specific relation to these things in Chapters 10, 11 and 12.

The computer metaphor is not just about memory and speed; it is also about how information is used, and progress in artificial intelligence during the 1970s saw a burgeoning number of computer simulations of human problem solving that were sometimes applied to the solving of classic Piagetian tasks (Halford, 1993). A particularly pertinent approach was called Production Systems as it described rules that could be modified in line with changes of state brought about by a given action (Young, 1976). These early perhaps rather brittle metaphors gradually gave way to more 'probabilistic' explanations of problem solving based on something more like the human mind. These were the **neural net**, or **connectionist** models, which could take account of the fact that mental processing can have many elements working in parallel. As models of learning mechanisms, these remain a valuable adjunct to empirical research in developmental psychology (Yermolayeva & Rakison, 2014).

EXECUTIVE FUNCTIONING

The recognition that there are many 'domains' of cognitive development is very much in tune with our rapidly advancing knowledge of brain function, which increasingly points both to the *multiplicity* of brain mechanisms and their complex functional *interconnectivity*. Although understanding the workings of the brain is still regarded as science's greatest challenge, the evidence from children's development is increasingly interpretable in these terms, and many contemporary explanations of developmental change make a direct appeal to neuroanatomical development. A central concept in this is **executive**

functioning (EF). This is a powerful concept, with widespread applicability to cognitive development, and we shall be returning to it frequently throughout the book. It has a very sound grounding in our understanding of a part of the brain called the **prefrontal cortex** and deals with the neural pathways that connect sensory information with other parts of the brain, including those involved in memory, decision-making and the planning of action. The prefrontal cortex is likened to a command centre that is involved in co-ordinating these connections. EF links behaviour with the brain by encapsulating the complex interplay between information gained through the senses, memory and attentional mechanisms in order to explain how plans are formulated and behavioural goals are achieved, and even what kind of mental processing is involved. A key element in EF is the ability to flexibly adjust to changes in the environment, affording greater individual control at the level of both thought and action. Whilst the EF approach points up the massive interconnectivity across domains of cognition, psychology's history – its own 'narrative' – has been very much concerned with the isolation of different aspects of cognition, such as perception, action, memory, language, thinking and reasoning, and so this book, like most, will chart the story of development in these terms, as the chapter titles make evident. But as the structure of the book also reflects, the interdependence of cognitive skills is a cumulative process; reasoning is based on what the child knows, and this on what is remembered, what is remembered on what has been encoded perceptually, and what is encoded perceptually on how the child moves and behaves in the world.

This brings us, at the end of this short introduction, to the most salient fact about understanding cognitive development: it is not about how 'the' mind grows by itself, it is about how the mind in a body grows in a world. Where Piaget was perhaps at his most prescient was in trying to understand cognitive development from the viewpoint of the child in a world with which he or she interacts both mentally and physically. So we shall now accompany the child, mind and body, on its voyage of discovery, starting with its first few minutes of life.