Psychology Press

A Student's Guide to DEVELOPMENTAL PSYCHOLOGY

MARGARET HARRIS • GERT WESTERMANN

A Student's Guide to Developmental Psychology

This major new undergraduate textbook provides students with everything they need when studying developmental psychology.

Guiding students through the key topics, this book provides both an overview of traditional research and theory as well as an insight into the latest research findings and techniques. Taking a chronological approach, the key milestones from birth to adolescence are highlighted and clear links between changes in behaviour and developments in brain activity are made. Each chapter also highlights both typical and atypical developments, as well as discussing and contrasting the effects of genetic and environmental factors.

The book contains a wealth of pedagogical features to help students engage with the material, including:

- learning objectives for every chapter
- key term definitions
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- further reading
- suggested essay questions.

A Student's Guide to Developmental Psychology is supported by a companion website, featuring a range of helpful supplementary resources including exclusive video clips to illustrate key developmental concepts.

This book is essential reading for all undergraduate students of developmental psychology. It will also be of interest to those in education, healthcare and other subjects requiring an up-to-date and accessible overview of child development.

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For Karl, Elise and Francesca, who have taught us a great deal about children's development

A Student's Guide to Developmental Psychology

Margaret Harris and
Gert Westermann

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Contents

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CHAPTER 1

CONTENTS

Framework and methods

1

After reading this chapter you will be able to

- formulate several of the big questions that we can ask about child development
- discuss the main aspects of the nature–nurture debate
- understand the concept of critical periods
- describe the main behavioural and neurophysiological methods used in developmental studies.

1.1 THE BIG QUESTIONS IN DEVELOPMENTAL PSYCHOLOGY

Studying the development of children can address many of the big questions that we ask about ourselves. If we want to understand why we as adults are what we are, we must understand how we get there. How do we learn and gain knowledge of the world? How is our character shaped, our abilities, our social skills? How much are we subject to the genetic endowment passed down from our parents, and to what extent are we affected by our experiences? Where does it all start – what abilities do babies bring to the world?

Studying children can, of course, also help us better understand their needs and what makes them thrive and flourish. How can we improve our children's lives? How can we provide them with an environment in which they feel safe and happy? Is their view of the world different from that of adults? How can we educate our children to become good people and good citizens, encouraging them to become adults who themselves care about the generations following them? Should we punish our children for transgressions, or should we focus on encouraging their good behaviour? How can we help children with learning disabilities such as developmental dyslexia, and developmental disorders such as autism?

Finally, in studying development we can try to answer questions about the developmental process itself: Why do children develop? What drives developmental change? How does a child move from not being able to do something to being able to do it? Do children take an active role in their development or are they merely the recipient of environmental stimulation, or subject to the genetically-determined maturation of abilities? Is the development of children's ability continuous or can we see stages in development, i.e. abrupt changes between phases of relative stability? If we observe such abrupt changes, does this mean that something inside the child is changing rapidly, or can a gradual change in underlying processes lead to sudden changes in behaviour and abilities? Are there specific ages at which abilities, such as speaking a language, can be learned and, if so, why?

It should be obvious that many of these questions are very important from a variety of viewpoints – helping children to thrive and be happy, helping society to create a positive environment and helping science to understand more about human development. The answers to these questions also have many practical implications, ranging from political decisions about the provision and quality of childcare, the right age to enter school, the structure of schooling and assessment, to giving parents the knowledge to judge the merits of educational toys, CDs and DVDs. No wonder that, through history, many of these questions have been debated with great passion and conviction – albeit sometimes not with the basis of factual evidence that one would wish for with questions of such importance. It is the task of developmental psychology as a sub-discipline of the science of psychology, to collect and evaluate evidence, to formulate hypotheses and to understand how development unfolds in the child.

We will now consider two of the main questions that have been asked about developmental change: the question of nature vs. nurture, and the question of critical periods for learning.

The nature–nurture debate

Why are we the way we are? Is it because of our biological predispositions – our genes – or because of the environment in which we have grown up, the experiences we have had? This question of whether children are predetermined by nature or shaped through nurture has been one of the most long-standing debates in psychology and, before that, philosophy. This is partly because, depending on the viewpoint one takes in this debate, one's view of how a society should be organised can be very different. If you believe in a predominantly biological basis for people's abilities and behaviour, you will see little benefit in trying to change them. There would be no use in trying to help weaker pupils in school through extra tuition and coaching – one is born with one's abilities, and that's that. Likewise, putting people who have committed a crime into prison would mainly serve two purposes: to punish them by taking away their freedom, and to protect society from them by locking them up.

Taking the view that people are the product of their experiences would, however, lead to very different conclusions. If it is the environment that makes us what we are, then by adapting this environment anything can be achieved. Anyone could be a genius, given the right environment! Or at least, one would put great emphasis on providing support for disadvantaged children because their weaker performance in school would be explained with not having had the same rich experiences and opportunities as their peers. As for prisons, one would put an emphasis on rehabilitating offenders so that the time spent in prison is a productive means to re-integrate people into society.

Given these wide-ranging implications it should come as no surprise that the nature–nurture debate has provoked controversy and that many different viewpoints have been articulated. Although the ancient Greek philosophers already had their views on this question, the debate was first labelled the 'nature-nurture problem' by Francis Galton (1822–1911), a polymath cousin of Charles Darwin, who was impressed by the tendency of genius to run in families (including his own). Galton speculated that there must be a strong inherited, biological basis for intellectual ability, and he argued for this view in his book, *Hereditary Genius* (1869).

Historically, most views have acknowledged that some parts of people's behaviours and abilities have a stronger biological component and others are more prone to be affected by the environment. A strong position about the importance of 'nurture' was articulated by the English philosopher John Locke (1632–1704). Locke believed that children were born as a '**tabula rasa**', a blank slate, and that all of their experiences would shape them into their final self. He wrote that we can imagine 'the mind to be, as we say, white paper, void of all characters without any ideas; how comes it to be furnished? [. . .] Whence has it all the materials of reason and knowledge? To this I answer, in one word, from experience: in that all our knowledge is founded, and from that it ultimately derives itself' (Locke, 1690, vol. 1, book 2, section 2).

Locke's strong environmentalist argument was partly a reaction to the widespread belief of his time that many ideas, such as the belief in God or some mathematical truths, were innate. According to his views (and we will return to them in some more detail in the next chapter), innate factors do not make important contributions to psychological development.

In contrast to Locke, Jean-Jacques Rousseau (1712–1778), a Swiss philosopher, took a more 'natural' view of human development. He believed that children grow according to nature's plan, best guided by nature alone, and that education by others was not a good way of forming a good human being. He believed that children are innately 'good' and that education, moral guidance and constraint would corrupt more than benefit them. His was the view of a '**noble savage**' unspoilt by society and contrasting with the corrupted product of education. This viewpoint emphasises the child's natural predispositions and minimises the role of education in forming the child. We will also return to Rousseau's ideas in the next chapter.

The nature–nurture debate has continued ever since these early philosophical arguments. Historically, there was little empirical evidence either way, but one source of evidence concerned so-called **feral children**: children who had grown up in the wild and were brought back to civilisation. There have been many reports of such children, with one famous case that of Victor, the Wildboy. Victor was captured in 1799 when he was 11 or 12 years old, wandering naked in the forests near Aveyron in southern France. Around a year later he was taken to Paris to great public interest. People wanted to see first hand the 'wild and noble savage' described by Rousseau. Instead they saw a disturbed child, incapable of speech, unable to maintain attention, spending his time rocking backwards and forwards. Victor was placed in the care of the physician Dr Jean-Marc-Gaspard Itard. Itard believed that Victor's deficits stemmed from a lack of socialisation and he set out to educate Victor over a period of five years. He attempted to teach Victor to speak but eventually had to acknowledge failure. By the time Victor died at age 40, he was able to speak only three words.

With Victor, as with other feral children, it was not clear whether their atypical behaviour was due to their unusual experiences – lack of parents and of social contact with other humans, potential traumatic experiences and so on – or whether they had a marked disability such as severe learning disability or autism. It may well have been that Victor was abandoned by his parents because he was abnormal in some

KEY TERMS

Tabula rasa
A blank slate.

Noble savage
A character unspoilt by society, in contrast to being 'corrupted' by education.

Feral children
Children who have grown up with little or no human contact.

A picture of Victor, the Wildboy, from Itard's book.

Twin studies are used by researchers to investigate the relative contributions of genetic predisposition and the environment to human behaviour and the interaction between genetic and environmental factors.

Identical twins reared in different circumstances apart from each other. (From Gottlieb, 1998 with permission from Harvard University Press.)

way. For this reason, although none of the feral children that were found ever resembled Rousseau's 'noble savage', it was recognised that the evidence they provided for the nature–nurture debate was questionable.

The advent of experimental psychology brought a new way to study the relative contribution of genetic predispositions on one hand and the environment on the other to human behaviour: this is the study of twins. **Monozygotic** (i.e. identical) twins are genetically identical, and therefore they come to the world with the same biological endowment. Any differences in the appearance, character and abilities of identical twins must therefore be due to the environment, that is, to nurture. Of course most twins grow up together and therefore they also share a large amount of environmental experiences. By contrast, **dizygotic** (non-identical) twins are genetically only as closely related as regular siblings (note that according to current estimates (Levy *et al.*, 2007) all humans share 99.5 per cent of their genes anyway by virtue of being human). Nevertheless, even dizygotic twins usually share many of their experiences.

In comparing large groups of identical and fraternal twins and observing the similarities and differences between twin pairs, scientists have estimated the contribution of genetic predispositions, the contribution of the environment shared by both twins and also the environment unique to each twin, to a large number of traits. For example, if identical twins are more similar in height than fraternal twins one would conclude that height has a relatively strong genetic basis, because both types of twins have a shared environment, but identical twins additionally have more shared genes.

However, twin studies have been criticised because their results might not be generalisable to the wider population. First, being a twin is different from being a single born child in a number of respects. Twins begin by sharing the womb and then, after birth, they share their parents' attention. They grow up with an identical-aged peer always around. Another criticism is that, although twin studies rely on the assumption that shared environments are the same for identical and fraternal twins, the shared environment of identical twins is different in many ways from that of fraternal twins. For example, identical twins spend more time with each other and they have more common friends than fraternal twins. Therefore, traits in which identical twins are more similar than fraternal twins might not be due to shared genes but to their greater shared environment. The debate on the value and validity of twin studies has not yet been resolved (Freese & Powell, 2003; Horwitz, Videon, Schmitz & Davis, 2003a, 2003b).

Many scientists now agree that thinking of nature–nurture as a dichotomy is not useful and that the question of which aspects of people's behaviour and abilities are due to genes and which to the environment is too simplistic. The reason for this emerging consensus is that it is becoming clear that nature and nurture are very closely tied together. Whereas the traditional view of genes was as a blueprint for development, we now know that the way in which genes function can be regulated by the environment (Gottlieb, 1998). Whether a specific gene becomes *expressed* (active) depends on signals it receives from other genes or hormones, and these signals can be affected by nutritional cues, physical contact, environmental stress, learning and other environmental factors. You can see a striking illustration of the impact of the environment on gene expression in the photo (page 4), which shows a pair of monozygotic twins who were reared apart in different circumstances. Despite identical DNA the twins differ very much even in traits such as height, which one might expect to be immune to experience. You can read more about the effects of experience on gene expression in Box 1.1 where we discuss epigenetics.

KEY TERMS

Monozygotic
Twins that developed from one zygote, so are genetically identical.

Dizygotic
Non-identical twins, genetically only as closely related as regular siblings.

Epigenetics
The study of how genes can be turned on and off by experiences.

BOX 1.1: EPIGENETICS

The field of **epigenetics** studies how genes can be turned on and off by experiences. Each of your cells contains identical DNA, and yet there are vast differences, for example, between a skin cell and a neuron in your brain. Why is this? During the development of the foetus, genes in individual cells are switched on and off by *epigenetic tags* so that only genes relevant to the final role of the cell remain active. More recently it has been discovered that such epigenetic tags work throughout life so that genes can be switched on and off due to experiences. There are several striking examples of this process and it has become clear that, not only can maternal behaviour affect the genetic tags of a baby in the womb, but also that we can pass on some of our own tags to our offspring.

An example of the effects of maternal experiences on the epigenetic makeup of the unborn child comes from a group of people born in the Netherlands during the Second World War. In the German-occupied Netherlands, food supplies had been cut off to the densely populated western cities, resulting in a great famine called the Dutch Hunger Winter that lasted from November 1944 to the late spring of 1945. Many people died and others survived on as little as 25 per cent of the normal food intake (Roseboom, de Rooij, & Painter, 2006). After the war ended, epidemiologists followed up on the long-term effects on the survivors of this severe malnutrition. Of particular interest were children who had been in the womb during the famine. Unsurprisingly, babies whose mothers were undernourished during the last three months of pregnancy were born small. In contrast, babies conceived during the famine but whose mothers ate normally for the final three months of

Lamarck theorised that acquired characteristics (such as a long neck, developed from reaching to eat leaves high up in a tree) could be passed on to offspring. Although Larmarck's idea was wrong in its specifics we now know that, to an extent, epigenetic information can be inherited.

pregnancy (after the famine had ended) had a normal birth weight.

But the long-term effects for these babies also differed. Those babies who had been born underweight stayed small throughout their lives and had below-average weight and below average obesity rates. However, the normal birthweight babies later, as adults, showed higher than average obesity rates than the general population. Although at birth they seemed perfectly healthy and normal, their mothers' malnutrition during the early stages of pregnancy had changed them in a way that made them more susceptible to obesity later in life. The way in which this effect from early foetal development to adult life was transmitted was found to be through atypical epigenetic markers on genes associated with growth hormones, cholesterol transport and ageing (Heijmans *et al.*, 2008).

There are many other examples of epigenetic effects, both in animals and humans (Carey, 2012). Epigenetics can explain why, in two people with the same genetic predisposition for a certain illness (e.g. diabetes, breast cancer), one of them might actually develop the illness while the other will not. This is because genetic predisposition and environmental effects (perhaps through smoking, over-eating, lack of exercise) act together to switch the relevant genes on and off.

Epigenetic research has even cast doubt on the long-held belief that acquired traits cannot be passed down to offspring. The idea that parents can pass on acquired traits was first advanced by the French naturalist, Jean-Baptiste Lamarck (1744–1829). One example he gave for his idea was that a giraffe, straining its neck to reach the leaves high in a tree, would gradually develop a longer neck. This acquired long neck would then be passed on to that giraffe's offspring who would be born with a longer neck than the parent giraffe had at birth. Lamarck's theory of evolution preceded that of Darwin's view of natural selection and, after the general acceptance of Darwin's far more plausible theory, it fell out of favour and was dismissed, and even ridiculed. However, while Lamarck's idea was wrong in its specifics – and his example may have been unfortunate – we now know that, to an extent, epigenetic information can be transmitted to offspring. While the traditional view was that all epigenetic information is erased in sperm and egg cells, it now appears that some of this information survives. The mechanisms by which this happens are currently a field of very active research. What is clear already is that the newly emerging understanding of epigenetics – the switching on and off of genes on the basis of experiences without changing the DNA – shows that nature and nurture cannot be separated.

Critical periods

A second big question in developmental psychology is whether there are time windows in development during which the learning of certain skills is possible or, at least, better than at other times. If you have learned a foreign language in school then you probably have an accent. If you learn to play the piano as an adult, the chances are that you will not be able to become a concert pianist. Why is this?

Scientists have, for a long time, recognised that the timing of development matters. Not every ability can be learned equally well at any age. The period of time during which a particular ability can be learned has been termed the **critical period**. One of the most striking examples of a critical period came from the biologist Konrad Lorenz (1903–1989). Lorenz carried out detailed observation on a number of species, including geese. When a gosling is newly hatched it forms a life-long attachment to the first moving object it sees and follows it around. This process is called **imprinting**: a biological predisposition for a behaviour that is triggered by, and linked to, a specific environmental stimulus. Normally the object on which the gosling imprints would be the mother goose, but Lorenz showed that goslings could imprint on a large variety of objects such as rolling balls or Lorenz's boots. Whatever the goslings imprinted on could not be reversed. According to Lorenz, a critical period is therefore characterised by the ability to learn only during a short, sharply defined period of life, and by the irreversibility of this learning later in life. You can read more about imprinting in Chapter 2.

Since Lorenz published his observations, it has become clear that the timing and duration of critical periods can be affected by experience. For example, the imprinting of domestic geese and chicks can be delayed if no suitable object for imprinting is present. For this reason, the term **sensitive period** is often used to refer to a time of heightened ability to learn. In human development critical/sensitive periods have been postulated for a large range of learned abilities, from the acquisition of language (with different critical sub-periods for different aspects of language such as phonology, syntax and so on), second language learning, for binocular vision, the ability to learn about solid food and the forming of attachments.

The main questions that researchers have asked about critical and sensitive periods are whether, and under what circumstances, they are flexible in onset and duration, whether what is learned during such a period can be reversed and what the origins of such periods are. These questions are important both for ensuring that children receive relevant experiences during development and for understanding what the consequences might be of not receiving the right kind of experience at the right point in development, and how this might be remediated. For example, the deprivation from a caregiver during the first years of life results in problems with emotional development and attachment, and a focus of research has been how these negative outcomes can be reversed or mediated by subsequent therapeutic interventions.

KEY TERMS

Critical period
The period of time during which a particular ability can be learned.

Imprinting
A biological predisposition for a behaviour that is triggered by, and linked to, a specific environmental stimulus.

Sensitive period
A time of heightened ability to learn.

Lorenz hatched some goslings and arranged it so that he would be the first thing they saw. From then on they followed him everywhere and showed no recognition of their actual mother. The goslings formed a picture (imprint) of the object they were to follow.

There are different possible explanations for why sensitive periods occur (Thomas & Johnson, 2008). One is maturation: at a certain point in development the neurochemistry of the brain might change so that plasticity – the ability of the brain to learn – becomes greatly reduced. If we imagine that the brain's flexibility in learning is based on many connections between neurons, the closure of a sensitive period for a particular ability could come about with the pruning of all those connections that have not been used. For example, initially the motor neurons in the brain might have many interconnections that would enable children to develop the finger dexterity necessary to play the violin. If a child actually learns to play the violin, these connections would be strengthened and stabilised. However, if this skill is not learned the necessary connections would be pruned and, once gone, it would be impossible to develop the same ability to play the violin that existed when all the original connections were in place.

A second possible explanation is that sensitive periods are a by-product of learning itself. Learning involves specialisation and, once specialisation has taken place, it is difficult to reverse this process and learn something new. In terms of the brain this could mean that a brain region might initially be responsive to a wide range of inputs. Through development, in interaction with other brain areas, this region would become more specialised. For example a brain region might become especially responsive to faces but less responsive to other visual stimuli. It would then be difficult to re-organise the brain so that this region again responds to a wide range of visual stimuli.

Finally, sensitive periods might just appear to end because the learning system has become stable as there is little more to be learned. For example, when growing up in a language environment, the brain adapts to the specific sounds and structures of that language. As long as the language environment is not disrupted there would then appear to be little change in abilities, but a complete change of this environment could de-stabilise this system and learning might again take place.

There are many disparate strands of research into critical and sensory periods, in different domains and with humans and animals. Much of the received wisdom of sharply defined, unalterable critical periods has been modified, and more scientists now question whether behaviours that have been observed in animals, such as imprinting, are relevant to understanding aspects of human learning and development, such as attachment. Research has been carried out on the neural mechanisms underlying plasticity in learning, and more is underway. We can say with certainty that there is certainly much more to find out about this topic.

1.2 COLLECTING AND INTERPRETING PSYCHOLOGICAL DATA

In conducting psychological research we plan and design studies, collect experimental data, analyse these data statistically and interpret our results. You will see many examples of this process described in this book. You will also see some examples where data have been collected but there are conflicting interpretations of the results. Because interpretations of the same data can be so different it is important to understand how the data were collected and what the link is between the data and the conclusions drawn from them. In this part of the chapter we will therefore explain some of the most common methods of collecting data in developmental psychology.

Longitudinal and cross-sectional designs

The topic of developmental psychology is the nature of change in children. We can examine this change in two principal ways. In **longitudinal** designs researchers follow a group of children over time, testing them at different ages. The main advantage of this method is that one can see how individual children change over time. There are fewer problems with individual differences between children: a child tested at different ages is still the same child. However, longitudinal studies are challenging for a number of reasons. First, they take a long time to carry out. For example, if you are interested in the effects of vocabulary size at age two on writing ability at age eight, it will take six years before you have an answer. Second, in longitudinal studies, there usually is a high drop-out rate: during the study many children will move away, or lose interest in participating. Therefore, a high number of participants have to be recruited at the beginning of the study to compensate for potential loss. Third, there might be a systematic difference between those participants staying in the study and those dropping out, and this could create a biased sample. For example, children who struggle with reading might be less likely to participate at age eight than those who excel at reading, and this non-representative sample could then lead the researcher to under- or overestimate the effect of early vocabulary size on reading ability.

In a **cross-sectional** design, different children at different ages are tested at the same time and are compared. For example, when studying the development of vocabulary between one and three years of age, one could test different groups of 12-, 15-, 18-, 24- and 36-month-olds and count the words that the children in each of the age groups can understand or produce. With this method it is not possible to study, for example, how predictive vocabulary at 15 months is for vocabulary at 36 months, since different children are tested at these ages, but one can measure how quickly vocabulary develops on average and find out whether it grows linearly or exponentially during that age range. Cross-sectional studies are faster and easier to do than longitudinal studies, but they also have their downsides. First, there will be greater individual differences among children in different age groups than in longitudinal studies, making it necessary to test more participants. Second, there could be systematic differences between the age groups, so-called *cohort effects*. For example, if the provision of early nursery education was increased, and the 18-month-olds had benefitted from this but the 36-month-olds had not, then it would be difficult to draw firm conclusions from a comparison of the vocabulary scores of these two age groups. Nevertheless, cross-sectional designs are by far the more common method used in developmental psychology mainly because they take considerably less time and money to carry out.

KEY TERMS

Longitudinal
A research design in which data are gathered from the same individuals over a period of time.

Cross-sectional
A research design in which children of various ages are studied at the same time.

Observational studies

Many developmental studies involve the observation of children's naturalistic behaviour. Such observation studies can make use of diaries where parents regularly record their child's behaviours or utterances. In recent years, however, it has become more common to use videotaping. This can be done, for example, by setting up cameras in the child's home or nursery, or by setting up recording sessions in a specially equipped lab (see the photo overleaf). Observation labs usually contain several cameras that can record the child from different perspectives. After the end

A child observation laboratory. One-way mirrors can be used to observe what is going on in the playroom.

of the session it is then possible to analyse the recordings in great detail. For example, by using slow motion one can analyse subtle behaviours that would be impossible to record from live observation. These settings are also valuable for studying the interactions between children or between children and their parents in an *ecologically valid* setting, that is, a setting that is similar to what children experience in their everyday life.

A drawback of using video recording is that it is very onerous to transcribe and analyse such recordings. In studies that analyse the language spoken by children it typically takes 20 hours or more to transcribe and code one hour of recording (Kirjavainen & Theakston, 2012). Therefore, most such studies involve at most one or two sessions per week. In a particularly rich study, one child (Brian) was recorded interacting with his mother during meal times and play sessions for a total of 330 hours from two years to nearly four years of age (Maslen, Theakston, Lieven & Tomasello, 2004). This involved a one-hour recording five days a week for 14 months and then four or five sessions per month for eight more months. The researchers estimated that the recordings captured around 8–10 per cent of Brian's utterances. Using such rich data led to some interesting insights. For example, the scientists found a difference between the frequencies of errors for past tenses (such as 'yesterday I eated ice-cream') and noun plurals (such as 'three blind mouses') that had not been found in earlier, less rich studies.

In an ideal world we would be able to record every waking moment of a child over a lengthy period of time, but naturally such an undertaking would pose formidable challenges as well as obvious ethical considerations. The first challenge is how to do the recordings. Asking the parents to carry a camera at all times is not an option, and even if the recordings were made, how could a researcher analyse at least ten hours of video and audio recordings per day, seven days per week? On the other hand this large amount of data could be very useful because we would get a very fine-grained record of the specific experiences of the child (such as face-to-face interactions with a parent, or the amount and type of language to which the child is exposed) and of the child's changing abilities.

In nature/nurture debates the precise nature of children's experiences is often a contentious issue. This is because children's knowledge in the absence of experience has been counted as a strong argument for the innate nature of that knowledge. For example, if a child expects that a ball that is hit by another ball will roll away without having experienced such an event before, it could be claimed that knowledge of cause and effect is part of our innate endowment (Leslie, 1995). By having a full account of a child's experiences we could check if this knowledge could have been learned. Likewise, in characterising developmental change as slow and gradual (continuous) or abrupt and rapidly changing (discontinuous) it is important to have fine-grained observations that will either confirm or disconfirm rapid changes in an ability. In short: to understand the causes and mechanisms of development we need at least a good understanding of the child's experiences and behaviours.

In other areas of science (e.g. genetics, physics) an approach called '**big data**' is becoming popular. The idea here is to collect as much data as possible and then develop automated, computer-based ways to analyse this data. In psychology as well this approach is taking a foothold (Ivry, 2013) and in developmental research some scientists now aim to record most of a child's first few years of life (see Box 1.2). One way in which a large data set has been used is to automatically differentiate early utterances from children with typical speech from those with language delay or autism (Oller *et al.*, 2010), showing that in early speech such differences already exist (see 5.2). Undoubtedly, this big data approach will become ever more important in psychological research in the future.

Related to observational studies are **clinical interviews** in which the researcher asks the child questions but tries to keep the conversation as open as possible. Depending on the child's response the interview can take different directions but the researcher can direct the conversation to find out more about the issue in question.

KEY TERMS

Big data
A research approach that involves collecting large amounts of data and using automated, computer-based methods to analyse it.

Clinical interviews
An interview in which the researcher asks questions but keeps the conversation as open as possible.

BOX 1.2: 'BIG DATA' STUDIES

In one example of a big data study (Roy *et al.*, 2006), a researcher installed cameras in the ceiling of every room in his family home and recorded his son's first three years almost in their entirety. These were 90,000 hours of video and 140,000 hours of audio recordings (Roy, 2009). This amount of data could not be transcribed and coded by hand, and the focus of work in this project was therefore to develop computerised methods of speech and video analysis. A similar large-scale project has used small sound recorders attached to a pocket in the clothing of young infants between 10 and 48 months of age to record them for whole-day sessions several times a month (Zimmerman *et al.*, 2009). This project resulted in 1,486 all-day recordings from 232 children and here, as well, software was developed to automatically identify and analyse the children's utterances.

KEY TERMS

Habituation
Method used to assess abilities of infants in which a stimulus is presented repeatedly until the infant's attention decreases significantly. Then a novel stimulus is presented and the increase in attention is measured.

Looking time and eye movement measures

The most common method of data collection in developmental psychology (and indeed, psychology as a whole) is to carry out an experiment and collect appropriate measures of children's behaviours. The advantage of this method is that many aspects of the environment and other key variables can be closely controlled. This allows for a more precise testing of hypotheses than observational studies.

Older children can be studied in similar ways to adults. We can ask them questions about their experiences, opinions and memories, and they can listen to and follow instructions to provide responses in experiments. You will find many examples of such studies in the chapters where we describe the development of children during the preschool period and beyond. Studies with very young children face particular challenges because they require different kinds of methods. Depending on their age, young children may not understand verbal instructions and may be unable to give verbal responses. Complex non-verbal responses such as choosing between alternatives may also be difficult. Finally, young children have shorter attention spans and they may not be willing or able to sit still for long enough to complete a study. For these reasons, researchers have had to develop alternative methods to examine the knowledge and abilities of young children and, especially, infants.

The measurement of looking time has become established as the main method for investigating infant cognition. The basis of this measure is the finding that infants usually prefer to look at something novel and unfamiliar compared with something old and familiar. One widely used technique that employs this finding is the **habituation** paradigm, which can, for example, be used to find out whether infants can discriminate between different stimuli. Infants are first shown one stimulus, for example a triangle, repeatedly on a computer screen and the time they spend looking at each presentation is measured. You can imagine that on being shown the same item again and again, looking times will gradually decrease as infants become less interested. When looking time has decreased by a certain amount (for example, by 50 per cent) we assume that an infant has habituated to this stimulus. Then, a novel stimulus, for example a square, is shown. If infants now look longer at the square than at the last triangles we can conclude that they can distinguish between the triangle and the square.

An important feature of this method is that it is *infant-controlled*: whether or not we proceed to the test phase (here: the square) depends on the infants' own looking behaviour. A related, non-infant-controlled method is the *familiarisation-preferential-looking* paradigm, which is also very popular (see the photo on page 13). Here, the familiarisation stimuli are shown for a fixed number of times (e.g. ten). A decrease in looking time across these presentations is assumed to show that the infants have become familiarised to the stimuli and have actively processed them. The familiarisation phase is followed by a test phase in which two objects are shown side-by-side: one is from the familiarised objects and one is a new object. If the infants look longer at the new object, as in the habituation paradigm, we assume that they can distinguish between the two objects.

In the *intermodal preferential looking* paradigm (IPL) looking behaviour in response to an auditory stimulus is assessed. This measure is useful, for example, in assessing infants' and young toddlers' understanding of words. For instance, infants could be presented with two pictures on a screen side-by-side, e.g. a cat and a ball. Two seconds into this presentation the word 'ball' is then played through

An infant participating in a familiarisation/novelty preference study. An eye tracker is positioned below the screen.

loudspeakers. If the infant then increases looking towards the ball we can assume that she understands the meaning of this word.

Another useful application of eye tracking is to see if children can predict the outcome of an event, for example the re-appearance of an object that is moving behind a wall, or the goal of an action. In a study to investigate action goal understanding (Falck-Ytter, Gredebäck & Von Hofsten, 2006), six- and 12-month-old infants as well as adults watched movie clips where an actor was moving a ball into a bucket. Eye-tracking of the participants showed that the 12-month-olds and the adults anticipated the outcome of the action and looked at the bucket before the actor's hand had reached it. In contrast, the six-month-old infants just tracked the ball in the actor's hand.

BOX 1.3: MEASURING LOOKING TIME

When looking time techniques were first developed, the looking times of infants were often coded online, by an experimenter pressing one button when the baby looked to the left and another one when she looked to the right. Another, more accurate way of coding was offline. This involved recording the infants' eyes with cameras placed above the screen where the stimuli are shown. After the study has finished the video recording can be analysed frame by frame to determine where the infant is looking at each time point. Although several researchers have written specific software for this purpose the scoring is nevertheless a laborious task and takes far longer than a testing session (around 15 minutes for one minute of video).

More recently, an increasing number of infancy researchers are using eye tracking to automate the scoring process. An eye tracker,

Left: the way in which an individual infant has scanned a face.
Right: A heat map of the areas of the face that were fixated by infants in a face processing study.

which is usually attached to the bottom or top of a computer screen, works by shining an invisible infrared light at the eyes of a participant and using an infrared camera to measure the reflection from the pupil and iris of the eye. Using complex computations the eye tracker can then determine where on the computer screen (or in a real scene) the participant is looking. Older eye trackers were sensitive to head movements and they were therefore either attached to the head, or participants had to place their head on a chin rest to minimise movement. Newer models can now compensate for a certain amount of head movement automatically, making them ideal for studies with infants and children. By using eye trackers the amount of time that the child spends looking at the displayed stimuli is measured online and is usually quite accurate. In addition, because the spatial resolution of eye tracking is high, rather than just distinguishing looks to the left or right side of the screen, eye tracking offers the possibility to examine more closely at which parts of an image (e.g. the head, tail or legs of an animal) the child looks, and in what order.

Eye trackers not only record the position of where someone is looking, but also the size of the pupil. It has been known for a long time that people's pupils dilate (become larger) when they are aroused, attentive or under high cognitive load (such as when solving a difficult maths problem). More recently scientists have begun to use pupil size in developmental contexts as well, where it is used to complement looking time measures to give a more fine-grained temporal picture of processing (Laeng, Sirois & Gredeback, 2012). Some researchers have argued that changes in pupil dilation can give a better measure of cognitive processing than looking times.

Imaging

In the past 20 years, methods have been developed that enable researchers to visualise children's brain activity while seeing objects or hearing sounds. Measuring brain activity directly has several advantages. First, it is not necessary for the child to show an overt response (such as looking longer at an object, showing surprise, or giving a spoken answer), and therefore brain measures can potentially pick up more subtle effects. Second, some of these measures (e.g. ERP, described below) are very time sensitive and this allows for the analysis of the timing of mental processes. Third, in being able to localise where in the brain certain processes occur, it is possible to compare brain function in children and adults and thus to gain further insights into how the brain changes across development and how these changes in the brain relate to changes in cognition. The ability to link brain and behavioural development has given rise to an entire new research field called Developmental Cognitive Neuroscience (Johnson & de Haan, 2011). In the following section we briefly describe the most common neuroscientific methods used with children.

Some of the established methods that are commonly used with adult participants are usually not suitable for use with children. For example, **functional Magnetic Resonance Imaging (fMRI)**, which measures regional blood flow in the brain that correlates with neural activity, requires participants to lie completely still in a narrow tube, often for long sessions, while wearing noise-protecting headphones. Children from around five years onward can be trained to lie still, but younger children move too much. Sometimes fMRI scans are done with infants but most of the few existing studies were done while the infants were asleep and did not move. Necessarily, the questions that can be addressed with sleeping children are limited. For example, one study using fMRI in three- to seven-month-old sleeping infants asked whether the infant brain processes emotional vocalisations (laughter, crying) differently from environmental sounds (Blasi *et al.*, 2011). The researchers found that, like in adults, the brain regions for processing these types of sounds differed considerably.

EEG and ERP

Far more common methods of measuring children's brain activity are **electroencephalography (EEG)** and **event-related potentials (ERP)**. In recording an electroencephalogram using EEG, a number of sensors (electrodes) are placed on the head and they pick up the tiny changes in electrical activity generated by neural activity in the brain. These small signals are then amplified and can be analysed.

KEY TERMS

functional Magnetic Resonance Imaging (fMRI)
A technique that measures regional blood flow in the brain that correlates with neural activity.

Electroencephalography (EEG)
A technique that uses sensors placed on the head to measure changes in electrical activity generated by neural activity in the brain.

Event-related potentials (ERP)
Specific waveforms of neural electrical activity that are derived from the EEG.

An fMRI scanner.

Using EEG it is, for example, possible to measure the synchronised firing of large groups of neurons at specific frequencies. Special interest in the developmental literature has focused on gamma-band activity: here, groups of neurons in the brain synchronise their firing at around 40 Hz (that is, the neurons fire 40 times per second). In infants, this synchronised activity has been linked to object processing. For example, when six-month-old infants watched an object on a screen that then disappeared behind an occluder, they showed a burst of such gamma-band activity in the temporal lobes, indicating that the infants were continuing to represent the object after it had disappeared (Kaufman, Csibra & Johnson, 2003).

Event-related potentials (ERPs) are specific waveforms of neural electrical activity that are derived from the EEG. For example, a researcher interested in the question of whether upright faces are processed in a special way might want to compare brain responses to seeing upright faces compared with inverted (upside-down) faces. The EEG signal is very noisy because it reflects all measured brain activity and not just that linked to looking at faces. The idea in ERP is that by using a large number of waveforms recorded when seeing faces, the non-face related parts of the EEG will average out and what remains is the response that is specific to faces. Therefore, in a typical ERP study participants view a large number of stimuli. For example, in a study that examined face processing in 12-month-old infants (Halit, de Haan & Johnson, 2003), the infants viewed up to 80 upright and 80 inverted faces. Averaging the brainwave responses to the upright faces and those to the inverted faces showed a characteristic response profile that differed between the two types of faces, suggesting that at this age infants, like adults, process upright and inverted faces differently. You can see the pattern of responses in Figure 1.1.

One of the main advantages of EEG and ERP measures is that they have a very high temporal resolution. This makes it possible to observe changes in neural activity on a scale of milliseconds and to observe the temporal unfolding of the processing of information. Despite this advantage, these methods also have a number of drawbacks. First, because electrical activity is measured by the sensors at the scalp it is not straightforward to infer from which parts of the brain the measured activity has originated, and it is therefore difficult to say precisely which parts of the brain are involved in processing a specific type of information. Second, the recorded neural activity is much smaller than the electrical activity generated by muscle movements. Therefore, if children move their eyes, head or jaw this creates so much electrical noise that the neural activity cannot be measured. As a consequence, in studies with infants many participants have to be tested. For example, in the study on face processing described earlier, 85 infants were tested but 58 of them moved around so

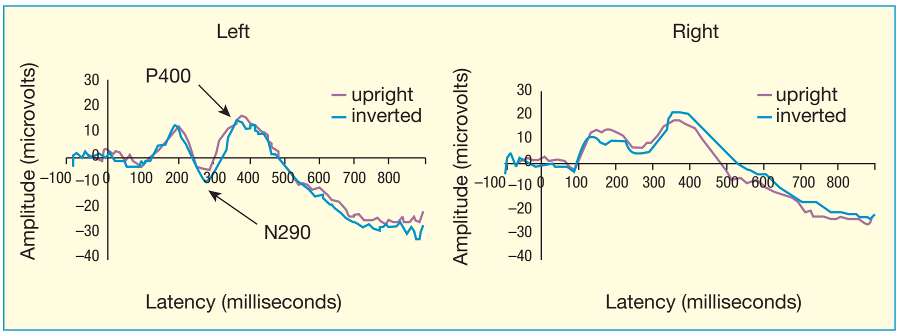

Figure 1.1
Pattern of responses. Reproduced from from Halit, de Haan, and Johnson (2003). Copyright © 2003, with permission from Elsevier.

much that their data could not be used. Nevertheless, ERP is currently the most widely-used neuroimaging method for children.

NIRS

A recent technique to visualise even young infants' brain activation is **Near Infra Red Spectroscopy (NIRS)** (Gervain *et al.*, 2011). This method is based on the observation that increased neural activity in a brain region is associated with changes in the oxygenation of blood in this region. Children wear a custom-made cap that contains LEDs emitting near infrared light of specific wavelengths, and light sensors that register the emitted light. The light travels through the skull and, depending on the amount of oxygen in the blood, is absorbed and scattered. The light sensors measure the amount of light reflected from the surface of the cortex and this can be used to calculate the level of blood oxygen that is linked to neural activity. NIRS has several advantages over other imaging methods: because the sensors are attached directly to the child's head it is not necessary to keep the head completely still as in fMRI and ERP. Furthermore, unlike fMRI but like ERP, NIRS is completely silent. The temporal resolution of NIRS is around five seconds, similar to fMRI, with a spatial resolution (i.e. to pinpoint where on the brain increased neural activity occurs) of around four centimetres (Shalinsky, Kovelman, Berens & Petitto, 2009). Finally, NIRS systems are relatively cheap, although at present there are only a few fully functioning out-of-the-box systems for developmental research. A drawback of NIRS is that, because light does not enter very deeply into the head, it can only probe the surface layers of the cortex and not deeper brain structures.

One well-known NIRS study investigated how newborns process language (Pena *et al.*, 2003). As you will see later (and may already know), in most adults language function is lateralised in the left hemisphere of the brain. In the NIRS study the researchers wanted to see if this lateralisation is already present at birth or if it develops gradually. To answer this question, newborn infants (two to five days old, alseep) were played three types of auditory stimuli: one was normal infant-directed speech, one was speech played backwards (which is usually not processed as speech) and one was silence. The researchers found that the infants showed increased activation in the left temporal area when listening to forward speech, but not to backward speech or silence. It therefore appears that left-hemisphere lateralisation of the native language is already present at birth.

This baby is wearing an EEG 'hair net'. Sensors placed on the head record the changes in electrical activity produced by neural activity in the brain.

KEY TERMS

Near Infra Red Spectroscopy (NIRS) A technique for assessing brain activation based on the observation that increased neural activity is associated with changes in the oxygenation of blood.

Computational modelling

The methods we have described so far all allow us to describe and measure children's behaviour or their brain activity. What they cannot do, however, is to explain these behaviours and patterns of brain activity, and they also cannot explain changes in behaviours and abilities across age. Computational modelling is a way to do this: to link observation with explanation.

Measurement of a baby's brain activity using NIRS.

KEY TERMS

Connectionist models
Models of learning implemented on a computer in which there are many interconnected nodes.

A computational model is in essence a computer program that mimics human behaviour. Importantly, it does so in a way that is based on our theory of how humans generate this behaviour. This approach differentiates computational modelling from Artificial Intelligence – there, scientists try to program computers so they display 'intelligent' behaviour but they are less concerned with whether the computer uses the same processing principles as humans. For example, chess computers can play chess very well and even beat the human world champion (Hsu, 2002), but everyone agrees that the way in which they play is very different from humans. A chess computer therefore is not a good computational model of human chess playing.

In a psychological computational model the aim is to accurately mimic people's behaviour, even the errors they make when they learn a task. When a new model has been developed, it can be exposed to an experimental situation that is similar to one in a psychological study. For example, when modelling a familiarisation/novelty-preference study we can develop a model of looking times. We can then show the model, like the infant, a certain set of objects, and examine if the modelled looking times are similar to those obtained from children. If they are then we can use the model as an explanation of the infants' behaviour and learning process: we know why the model performs the way it does (since we developed it), and an assumption can then be that the infants' behaviour is based on the same principles as those used in the model.

In developmental psychology in particular, a specific type of computational models called *artificial neural networks* or **connectionist models** have become popular. Connectionist models (Figure 1.2) are loosely inspired by the way that neurons function in the brain. As you perhaps know, a neuron generates electric impulses in its cell body, and these impulses travel along the neural axon to its synapses. At the synapse, which is a connection between two neurons, the electrical signal leads to the release of neurotransmitters, which are taken up by the other neuron where they are re-converted into electricity. This electric charge travels through the neural dendrites to the cell body. If this incoming electric signal is high enough the neuron itself fires an electric impulse.

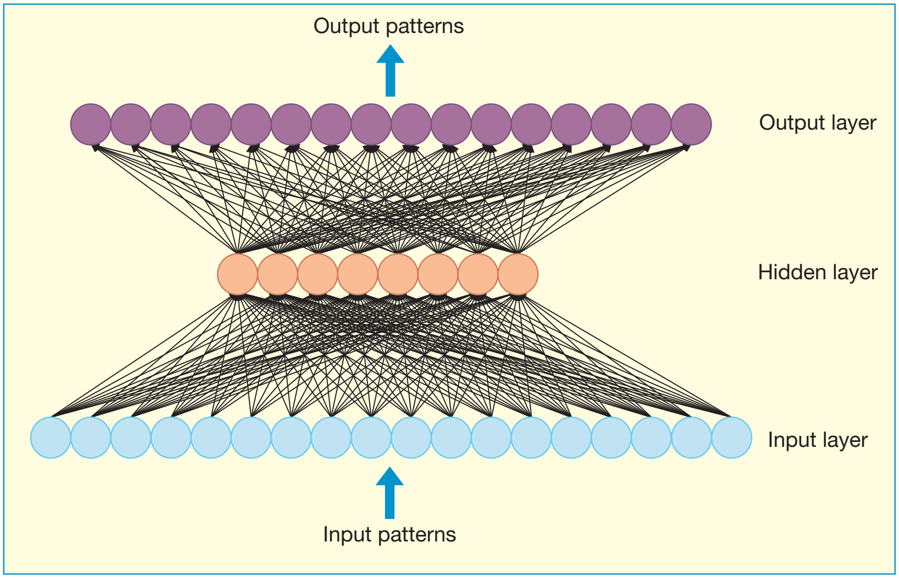

Figure 1.2
A simple neural network.

Neural processing – and thus, thinking, sensing, acting – can be described as originating from the exchange of electric impulses across biological neural networks. Each single neuron thereby performs a simple function: it integrates (adds up) the activation received through its dendrites, and if this activation is high enough, it generates an electric impulse (spike) which then travels along its own axon and synapse to other neurons. A neuron does not 'know' if it is processing visual, auditory, motor or any other kind of information; the principle of summing up incoming activation and sending activation to other neurons is common to all neurons. Learning happens by changing the strength of a synapse so that the amount of neurotransmitter that is released and taken up varies over time (learning can also involve generating new synapses or pruning existing synapses).

Artificial neural networks are meant to capture these (necessarily brief and oversimplified) basic operating principles of biological neural networks. The units in a network sum up the activation they receive through their incoming connections. This incoming activation is then transformed into activation of the neuron, which is sent through its outgoing connections to other neurons. What makes connectionist models attractive for modelling developmental phenomena is that they can learn from experience, by increasing or decreasing the strengths of the connections between the units. You can find out more about how this happens in Box 1.4.

From a psychological perspective the learning that takes place in computational models is interesting because we can observe how learning actually proceeds. For example, in a model that learns the names for objects (see Box 1.4), we can find out which names are learned first (perhaps those for more frequently seen objects, or those for objects with highly characteristic features), which names are hard (perhaps cases in which two very similar objects have different names, such as birds and bats) and whether the learning of names is linear or non-linear (that is, if there is a sudden spurt in which the model learns many names in a short time after being initially very slow at learning). We can then compare our findings of how the model learns names for objects with what we know about how children learn them. If we find that the model learns in similar ways to children – that is, it finds the same names easy and hard to learn, and it shows the same overall learning profile – then we can say that the model provides a good explanation of children's learning. But what does this mean? We know that the model learns names for objects simply by associating the visual appearance of objects with their name, and the characteristics of learning performance come out of this simple association process. So if the model's behaviour corresponds to that of children, this is the same claim we could make about children's word learning.

The explanation of human processing that is provided by a computational model can be further evaluated by considering the *predictions* such a model can make. In our example, after the model has learned all the names for the objects we have presented, we could 'damage' it by removing some of the connections between units. This damage would most likely make the performance of the model worse and it would lose the ability to name all objects it had learned. We can then study precisely which names get affected the most by damage and which others are more robust to damage, and we could make the prediction that adults who have had a stroke or who are suffering from dementia might show a comparable profile of breakdown in their ability to name objects. If this prediction turns out to be accurate this would be additional evidence for the validity of the model.

KEY TERMS

Backpropagation algorithm
An algorithm for learning in connectionist networks.

BOX 1.4: HOW CONNECTIONIST MODELS LEARN

Many connectionist models are organised like the one in Figure 1.2 (although some are considerably more complicated). Units are arranged in three layers. The input layer receives information from the environment, which means that some of the input units will become activated. This activation then flows through the connections to the intermediate hidden layer (which is called 'hidden' because it is not connected to the external world). There, based on the incoming activation, the hidden units will become active to different degrees and send on their activations through the connections to the output layer.

In this type of network the model typically learns a task that is given by a teacher. For example, the model might be used to learn the names for different objects. The input to such a model could then be a representation of the visual appearance of an object, and the output the phonological representation of the name of the object. Initially, before the network has learned anything, the strengths of the connections are set to random values. This means that when the model is presented with an object and activation flows through the hidden to the output units, the output will not be meaningful. The model, however, can learn to produce the correct name for the object, and this learning is achieved by changing the strengths of the connections. This works as follows: when the model is producing an output, this output is compared with what the model should produce (i.e. the correct name for the object, also called the target). Some of the output units of the model will be more activated than they should be, and some less. In essence then, the connection strengths (also called weights) are changed so that those that feed into units that are too active are reduced and those feeding into under-active units are increased. In this way, the activation pattern that the network produces gradually becomes more like the (correct) target pattern. The most popular method for computing the weight changes is called the **backpropagation algorithm**.

1.3 SUMMARY

In this chapter we have considered the questions that can be asked and answered within the framework of developmental psychology, and we have gone into some detail for two of these questions: the nature–nurture debate, and the question of critical or sensitive periods in development. Then we described methods by which we can study the development of children. While older children can be tested like adults, specific methods used with younger children are based on looking time analyses. We discussed a number of methods to study how the developing brain processes information, mainly EEG/ERP and NIRS. Finally, we discussed computational modelling with artificial neural networks as a way to develop and test theories of development and developmental change. At the end of this chapter you should now be equipped with knowledge of the questions we ask in developmental psychology, and the ways in which we set out to answer them.

FURTHER READING

Carey, N. (2012). *The epigenetics revolution: How modern biology is rewriting our understanding of genetics, disease, and inheritance*. New York: Columbia University Press.

Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness. A connectionist perspective on development*. Cambridge, MA: MIT Press.

Harris M. (2008). *Exploring child development: Understanding theory and methods.* London: Sage Publications.

Lewkowicz, D. J. (2011). The biological implausibility of the nature-nurture dichotomy and what it means for the study of infancy. *Infancy*, *16*(4), 331–367.

ESSAY QUESTIONS

1. Critically discuss the nature–nurture debate.
2. ‘Genes make us who we are.’ Discuss.
3. Are there critical periods in development?
4. Give examples of the use of imaging methods in infant research and discuss their benefits and drawbacks.