# 1

# THE NATURE OF DEVELOPMENT

The aim of this book is to explore different ways of thinking about and studying children's development. As in any other science, research in developmental psychology aims both to describe and explain the phenomena under investigation: the particular aim of developmental psychology is to describe and explain developmental change.

It is worth taking a moment to clarify the special nature of developmental change. Change occurs all the time and at many different levels, and it can be both positive and negative. Change in a positive direction, that is towards greater accuracy and better organisation, is regarded as being 'development'. So, in speaking of developmental change, I am talking about change that can be seen as part of the process by which, over time, children move from a less mature to a more mature way of thinking and behaving where greater maturity is seen as being more adult-like. It is worth noting, however, that developmental change does not always show a smooth trajectory from lesser to greater maturity, as we see later in this chapter. This has implications for both the description and explanation of development.

Describing developmental change is considerably easier than explaining why it occurs. An overview of models of development (Valsiner, 1998) draws the rather pessimistic conclusion that:

> Child psychology today is surprisingly free of interest in building models of general development. The discipline is filled with hyperactive attempts to accumulate data, but attempts to make sense of the data, in terms of models of basic developmental processes, are relatively rare. (Valisner, 1998: 189)

A rather similar observation is made in the opening chapter of *Rethinking Innateness* where the authors note that:

> Ironically, in the past several decades of developmental research there has been relatively little interest in the actual mechanisms responsible for change. (Elman et al., 1996: 1)

Although description is the easier task, it is useful to begin by considering what kinds of change developmental psychologists are attempting to describe. For, as we will see later in this chapter, theories of developmental change are intimately bound up with underlying notions of the nature of change itself.

## Transformational and variational change

It is useful to distinguish two major kinds of developmental change that can be described as *transformational change* and *variational change* (Overton, 1998). Transformational change refers to change over time, from conception and the prenatal period through infancy, early and middle childhood to adolescence, adulthood and old age. As children grow older, they show transformational change in almost every aspect of development. They undergo huge physical and mental changes as motor, social, emotional and cognitive skills develop. Many aspects of transformational change in different areas of development are interrelated and understanding one aspect of change (for example, in a particular cognitive skill) may also involve understanding how this relates to other changes that are occurring at the same time (for example, in social skills).

Variational change refers to variation within development at a particular point. Consider, for example, children's ability to reason. This undergoes striking transformational change from infancy to adolescence but, at any given age and developmental level of thinking, children will use a variety of different solutions to a particular problem – this is variational change. Interestingly, individual children will often not only vary from each other in their problem-solving strategies but the same child may use a different strategy from one day to the next or even from one question to the next within the same session.

All abilities – both mental and physical – are subject to transformational and variational change. However, the interrelation between the two dimensions of change is more clearly spelled out for some aspects of development than for others. One aspect of development where there has been a great deal of investigation of both dimensions of change is children's reading. In general, children become better at reading as they grow older and there are a number of different theories to explain how the nature of reading changes with age. However, some children are much better at learning to read than others. This means that understanding the processes by which children learn to read requires not only an explanation of transformational change, that is how children's reading strategies develop over time, but also an explanation of variational change, that is how the reading strategies of good readers differ from those of less good readers. Furthermore, if we consider reading as a global phenomenon, we also have to explain why the speed with which children learn to read is different in different countries; and also why there are national differences in the incidence and severity of reading difficulties.

A key aspect of understanding variational change is to be able to describe the course of development for a typically developing child so that it is then possible to identify and describe atypical progress. Thus, in the case of reading, we need to know what level of reading is age-appropriate for any given script. This, in turn, requires information about the range of variation in reading ability at a given age so that we can distinguish among good, average and below average readers and typical and atypical use of particular strategies.

## A developmental systems perspective

What kinds of theory best account for both transformational and variational change? Early developmental theories tended to argue for 'either/or' accounts of the influence of genetic factors or the environment on development (Harris & Butterworth, 2002). The term 'nature-nurture' was first coined as long ago as 1869 by Francis Galton in his book, *Hereditary Genius*, but fierce arguments between nativists and empiricists continued for much of the twentieth century with developmental change being seen either as the 'mere triggering of innate knowledge' or as 'inductive learning' (Elman et al., 1996).

One vivid illustration of the opposition of these 'either/or' kinds of explanation can be seen in the controversy that surrounded the work of Margaret Mead, the celebrated anthropologist. Mead's seminal study of adolescents in Samoa (Mead, 1928) claimed that the pattern of adolescence that characterised Western societies was not evident among the population of Samoa. The forward to the book, written by Boas, an eminent anthropologist who was Mead's mentor, set out the main conclusion:

> In our own civilization the individual is beet with difficulties which we are likely to ascribe to fundamental human traits. When we speak about the difficulties of childhood and adolescence, we are thinking of them as unavoidable periods of adjustment through which everyone has to pass. … The results of [Mead's] painstaking investigation confirm the suspicion long held by anthropologists, that much of what we ascribe to human nature is no more than a reaction to the restraints put upon us by our civilisation. (Mead, 1928)

Mead's claim that adolescents in Samoa were 'gentle, uncompetitive and guilt-free' (Grosskurth, 1988) was seen as strong evidence that development was shaped by the environment, a view that chimed with the American public of the times and resulted in Mead's book becoming a bestseller.

Mead's chief critic, Derek Freeman, strongly contested this view of Samoa, arguing that Samoan adolescents displayed the same patterns of emotional extremes that were evident in Western culture (Freeman, 1983). Undoubtedly, the truth about the influences of nature and nurture on adolescence lies somewhere in between these extreme views, and, although there are differences of emphasis, modern accounts of development tend to assume that developmental change occurs both as a result of maturation and growth and through the interaction that children have with their environment. As Elman et al. (1996) note:

> We believe that an interactionist view is not only the correct one, but that the field is now in a position where we can flesh out this approach in some detail. (Elman et al., 1996: xii)

One important factor in the current ascendancy of interactionist theories is that there is now a more sophisticated understanding of the way in which genetic factors operate (Gottlieb, 2007; Rutter, 2007; Westermann et al., 2007). Some of the arguments in this area are complex but, for present purposes, the key point is to recognise that there are important reciprocal influences within and between the different levels of development within an individual. Thus, genetic activity, neural activity, behaviour and the physical and socio-cultural effects of the environment all interact. I return to this issue in the next section.

Modern developmental accounts also look both at effects that operate at the level of the individual and those that are evident within a particular social group or culture. They do not, as Lerner puts it so elegantly, 'force counterproductive choices between false opposites; rather, these issues are used to gain insight into the integrations that exist among the multiple levels of organization involved in human development' (Lerner, 1998).

Of necessity, modern theories of development are complex just because they consider the interrelation of many different influences on development; and perhaps this is one reason why, as we have already noted, research often concentrates on data collection and interpretation rather than wider implications for developmental theory.

## The epigenetic landscape and beyond

To illustrate some of the issues that arise in adopting what might be described as a developmental systems perspective (Lerner, 1998) it is useful to consider one early and very influential model, Waddington's 'epigenetic landscape' (Waddington, 1975) in light of the most recent development in understanding gene-environment interactions that are discussed later in this section.

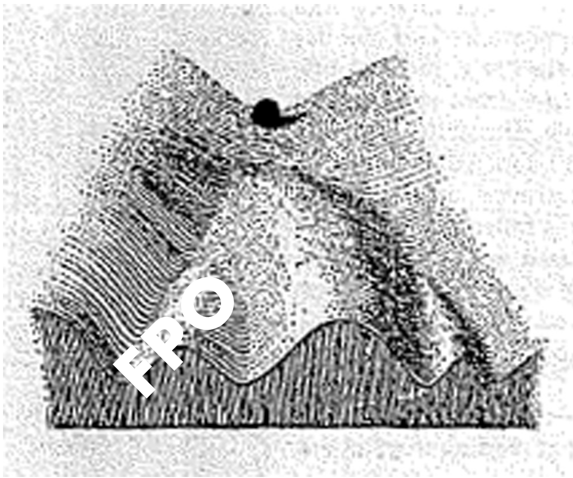


Figure 1.1 *The epigenetic landscape (based on Waddington, 1957); from Harris & Butterworth, 2002: 38*

Waddington, whose work has more recently been discussed as an underlying model for connectionism (Elman et al., 1996), was concerned with the complex relationship between the phenotype and the genotype. The phenotype, that is how an individual looks and behaves, is the result of an interaction between the genotype (the pattern of genes) and the environment. Waddington's metaphor of the epigenetic landscape was intended to explain the nature of the interaction between genotype and environment. He envisaged development as:

> a set of branching valleys in a multidimensional space that includes a time dimension, along which the valleys may extend. The development of the phenotype of an individual proceeds along a valley bottom; variations of genotype, or of epigenetic environment, may push the course of development away from the valley floor, up the neighbouring hillside, but there will be a tendency for the process to find its way back. (Waddington, 1975: 258)

The ball in Waddington's diagram represents the developing organism. The ball rolls downhill through a landscape made up of hills and valleys. These represent possible pathways that the development of an individual may take. The pathway taken by the rolling ball, as it progresses downhill, is constrained by the landscape but it is also affected by environmental events. These two factors interact. For example, if the ball is knocked off course (i.e. away from the valley floor), much greater force is required to move the ball out of a deep valley than out of a gently sloping valley. This reflects the fact that the consequences of a particular environmental factor will vary considerably according to where and when in development it occurs. Some aspects of development are very susceptible to environmental influence while others are much less so.

Another important feature of the epigenetic landscape is the incline of the valley floor into which the ball descends. All the valleys are inclined so that the ball will tend to roll forward (representing development over time) but in some valleys the floor has a gentle incline while, in others, the incline is much steeper. The ball will roll rapidly downhill in a valley where the incline is steep but progress will be slower where the incline is gentler. This represents the relative speed of development at different points.

The metaphor of the epigenetic landscape elegantly illustrates one way to think of possible pathways that development can take. It alerts us to the possibility that development can proceed along many alternative pathways that end up at the same place. It shows us that proceeding along a particular pathway early in development will have consequences for later development. It also leads us to expect that there will be important individual differences in both the rate and course of development in spite of similar end points; and, finally, it reminds us that development may not end up in the same place for all children.

Recent studies suggest that this picture of development is even more complex than the metaphor of the ball rolling downhill through the epigenetic landscape might suggest. Gottlieb (2007) introduces the notion of 'probabilistic epigenesis'. This contrasts with the traditional view of predetermined epigenesis, that is, the idea that genetic factors determine neural structures that, when mature, function in particular ways. In other words the sequence that is assumed in traditional epigenesis is:

genetic activity → structure → function

The key idea behind probabilistic epigenesis is that influences at the different levels of development are bi-directional. As Gottlieb puts it, 'neural (and other structures) begin to function before they are fully mature and this activity … plays a significant role in the developmental process' (Gottlieb, 2007). These mutual, bi-directional influences are depicted in Figure 1.2.

One of the examples that Gottlieb gives to illustrate his approach is the relationship between maternal behaviour in early infancy and patterns of attachment. A common finding is that there are relationships between patterns of maternal interaction in early infancy and later patterns of infant attachment (Harris & Butterworth, 2002). Gottlieb cites the finding that mothers whose interaction is classed as 'intrusive' when their infants are 3 months old are likely to have children who are classed as 'insecurely attached', that is, they tend to stay close to their mother in an unfamiliar situation and are very upset, and not easily comforted, when she leaves

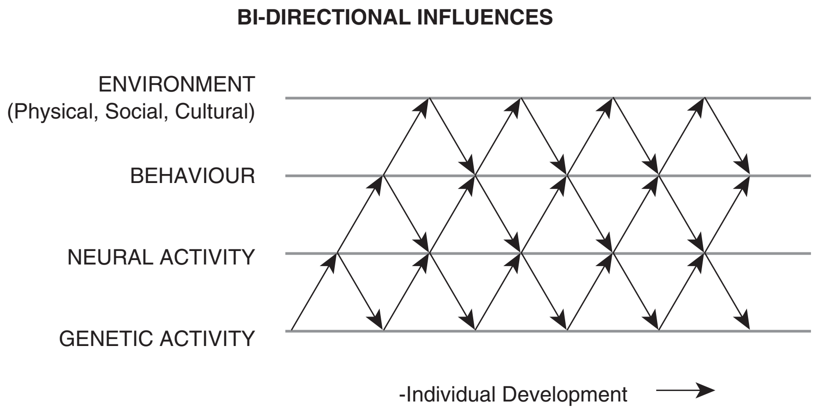


Figure 1.2 *Probabilistic epigenesis; from Gottlieb 2007: 2*

them with a stranger (Lewis, 1990). Gottlieb argues that understanding the sequence of cause and effect involves looking not only at how a mother's behaviour might affect her child's development but also considering how the mother's behaviour might be affected by her child's early behaviour. The suggestion is that mothers may be over-stimulating because their children are not socially oriented at a young age, preferring to focus on objects rather than people. With such infants, mothers are likely to be more proactive in their attempts to provoke social engagement whereas, in the case of more socially oriented babies who spontaneously send out lots of social signals such as looking at the mother and smiling, such attempts are not necessary. Indeed the most common pattern is for the mothers to be predominantly responsive to their infants rather than proactive. The suggestion is that over-stimulation – repeatedly trying to provoke a response – may then lead to insecure attachment.

One might also note that the tendency to focus on objects rather than people may well be the result of a genetic predisposition that might be present in both the infant and the mother. Thus genetic effects may also have a role in shaping the child's environment as well as working more directly.

Gottlieb illustrates the complexity of gene–environment interactions – or coactions as he prefers to call them – at other levels of development. For example, in rhesus monkeys, low serotonin metabolism is associated with higher levels of impulsivity, aggression and risk taking. In humans, low serotonin levels are associated with alcohol abuse and depression. At the genetic level, the level of serotonin metabolism is associated with the presence of a long or short allele in the serotonin transporter gene (5-HTT). Significantly, however, the genetic effects are mediated by the effects of rearing (Bennett et al., 2002). For monkeys who are reared with their mothers, seratonin levels are not related to the form of the 5-HTT gene. However, for monkeys who are reared only with peers (and therefore subject to more stress in early development), higher serotonin levels are related to the presence of the short allele.

One final study cited by Gottlieb (2007) is also worth mentioning. A recent study (Hood, 2005) compared the levels of aggression in selectively bred mice. Isolated rearing tends to increase the level of aggression in some strains of mice and so the idea was to look at the effects of rearing on the expression of aggression in mice who had been selectively bred to show either high or low levels of aggression. The results were striking. When reared socially, both strains of mice showed similar levels of aggression. However, for mice reared in isolation there were large differences in the aggression levels of the two strains.

This example clearly illustrates how aggressive behaviour in mice is the result of a gene–environment interaction. In mice, where both selective breeding and rearing can be carefully controlled, it is possible to begin to explore this interaction in ways that are not possible for humans. However, there is every reason to suppose that similar kinds of interactions and coactions operate in human development.

## Are there stages in development?

The model of the epigenetic landscape might suggest that the course of development is best understood as a continuous process of change. However, the location of junctions between the valleys can be seen as representing a point of transition between one stage of development and the next. Piaget, whose own thinking was very much influenced by the work of James Mark Baldwin (Harris & Butterworth, 2002), used the concept of stages in his theory as a way of distinguishing discrete periods in development that were qualitatively distinct from one another.

There are a number of different criteria for identifying developmental stages (Flavell, Miller, & Miller, 1993). First, as I have already implied, stages are characterised by *qualitative* changes. A qualitative change is not simply a matter of being able to do more of something but of doing it differently. Qualitative changes are relatively easy to spot in some areas of development, such as gross motor skills. Most babies begin to move around by crawling (or bottom shuffling) and then, later on, they acquire the necessary co-ordination to walk. Crawling and walking are qualitatively different types of locomotion. Drawing a distinction between qualitatively different kinds of cognition such as thought and language is arguably more difficult than in the case of motor skills.

Even where there is evidence of a qualitative change this does not, on its own, provide evidence for a transition between stages. Transitions are also marked by *simultaneous* changes in a number of aspects of children's behaviour. For example, between the ages of three and four years, children show a change in their ability to carry out a number of cognitive tasks. These include tasks designed to assess Theory of Mind understanding (Wimmer & Perner, 1983), appearance-reality tasks (Flavell, Green, & Flavell, 1986), and multi-dimensional card sorting (Towse, Redbond, Houston-Price, & Cook, 2000). Simultaneous changes in the ability to do such tasks suggest that a stage change, perhaps in ability to deal with more than one representation or dimension at a time, is occurring between the ages of 3 and 4. The possibility of a wide-scale change in ability points to the importance of looking at development from a broad perspective rather than merely concentrating on a single aspect of developmental change.

A third feature of stage transitions is that they are typically *rapid*. It may be relatively easy to spot a period of rapid physical change. For example, as children move into adolescence, they often go through a growth spurt in which they gain several inches in height and several pounds in weight in a few months. Similarly rapid change can be observed in other areas, such as children's language ability. Once the first 30 or so words have been acquired, many children show a sudden increase in the rate at which they learn new words (Fenson et al., 1990).

Stage theories are very common in developmental psychology. As we have already noted, Piaget is the best known proponent of a stage theory of development but many other theorists, including Freud and Vygotsky and neo-Piagetians, such as Robbie Case (Case, 1985), have used the notion of stages. There are, however, other ways to view development as we see in the next section.

## Linear and non-linear change

A rather different way of thinking about qualitative changes in development is evident in dynamic systems theory. This approach aims to produce a mathematical model describing how qualitative changes come about through the accumulation of small scale quantitative changes. In this way, dynamic systems theory accounts for qualitative change without the need to appeal to the notion of discrete stages.

The key to dynamic systems theory is that it attempts to model non-linear dynamics. There are two sorts of dynamics: *linear* and *non-linear*. The theory of linear dynamics is most obviously applied to mechanical interactions, such as a collision between two billiard balls: change is smooth and continuous and the new pathway that a ball will take after it has been hit by another ball can be precisely predicted from such factors as the angle and speed of collision. However, while linear dynamics can account for mechanical interactions, the patterns of change that occur in biological development are seldom smooth and continuous. Indeed, many apparently linear patterns of change over time come about either because only a restricted age range is considered or because researchers average data gained from a heterogeneous sample of children (Elman et al., 1996).

To take a simple example from Elman et al. (1996), if we were to plot the size of children's shoes against their age, the resulting function might well be linear if only data from children aged between 5 and 11 years were to be included. If we included data from older children, the resulting slope of the graph would no longer be linear as we would see the characteristic growth spurt in shoe size as children enter adolescence. Similarly, data collected from a large sample, containing children who come from diverse socioeconomic and ethnic groups, might appear to be linear. This is because there would be wide variation among children of the same age and this would average out into a linear increase. However, if the sample were to be restricted to children from similar backgrounds, the underlying pattern of non-linear change would emerge.

Dynamic systems theory uses non-linear dynamics to model developmental change (Thelen & Smith, 1994; van Geert, 1998). One of the strengths of dynamic systems theory is that it points to the great variety of different patterns that developmental change may take. In their analysis of what they call 'the shape of change', Elman et al. (1996) describe six different forms of change, only one of which is linear. Some of the most important patterns are shown in Figure 1.3.

The pattern of change shown in 1.3c is commonly found in developmental psychology. The example used by Elman et al. (1966) is of the relationship between age (in months) and the number of different words that children can say. Initially children learn words at a slow rate but, the more words they know, the faster the rate at which they learn new words. Other patterns of change may look more like 1.3b. Here, children initially develop at a very fast rate but, over time, the rate of development slows down. I discuss some examples of this pattern of change in the next section.

In light of our earlier discussion about developmental stages, the pattern shown in 1.3d is particularly interesting. Unlike the three other examples, this shows discontinuous change and what looks like a stage transition. However, both dynamic systems theory (van Geert, 1998) and connectionist modelling (Elman et al., 1996) show how the gradual accumulation of small changes over time can give rise to a sudden, step-like change.

## Information processing approaches

Another way of looking at developmental change is through the information processing approach. Like dynamic systems theory, the information processing approach emphasises detailed analysis of the processing demands of individual

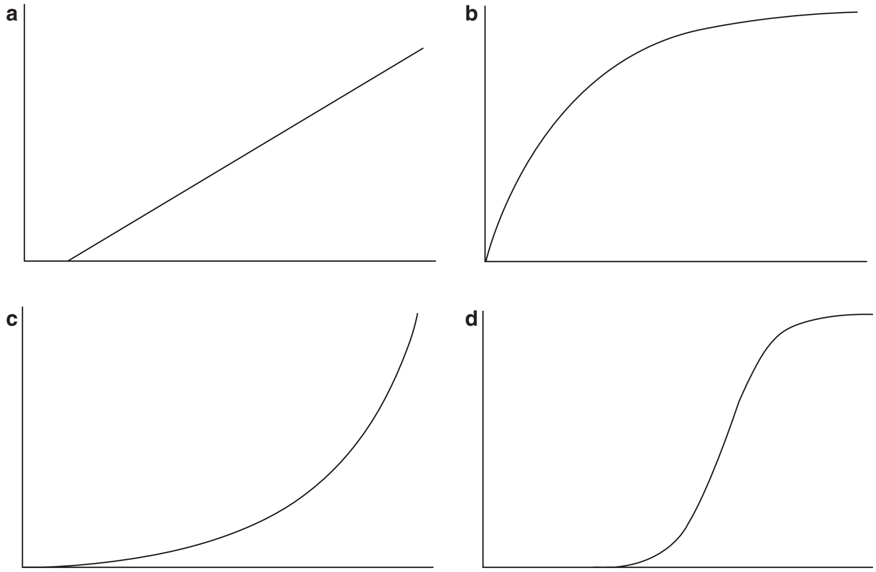


Figure 1.3 *Some examples of linear and non-linear forms of change;* adapted from Elmen et al., 1996: 176, 186, 191

tasks and their modelling in computer programs (Klahr & Wallace, 1976; Siegler, 1998). The main idea is to consider how children's abilities to meet the processing demands of a particular task change over time. One important aspect of a task is the memory load it imposes. A particular task may require a certain number of items to be held in memory at the same time and so this aspect will prove problematic for young children who can only remember a small number of items. Similarly, a particular task such as sorting cards according to their category may require a child to deal with two dimensions, such as colour and shape, that are changing independently but are interrelated (Towse et al., 2000). Children below a certain age will find it difficult when they have to take account of two dimensions simultaneously.

The most detailed information processing account of development has been developed by Siegler (Siegler, 1998; Siegler & Alibali, 2005). Some of Siegler's most influential work has looked at developmental changes in problem solving. Siegler outlined four stages that are evident in the way children attempt to solve problems involving a balance scale (see Figure 1.4). Children are shown a scale with weights placed different distances from the fulcrum and their task is to decide which side of the balance will go down. This is a difficult task because it involves taking into account both the weights on either side of the fulcrum and the distance of each weight from the fulcrum.

Siegler identified four different rules that children could use to solve balance scale problems. These rules differ in the extent to which they take

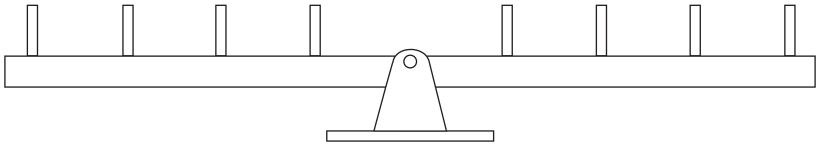

Figure 1.4 *Balace scale used by Siegler. Metal disks are placed on a Peg on each side of the fulcrum. Children need to decide which side of the balance will go down, given the particular configuration of weights on pegs*; from sieglar Alibali, 2005: 349

account of both weight and distance. Siegler showed that the way children performed on particular balance scale problems could reveal which of the four rules they were using. As you might expect, there turned out to be a general developmental progression in the use of the rules. Young children took account only of the weights on either side of the balance scale when they predicted which side would tip down (Rule 1). Older children were able to take account of distance if the weights on either side are equal (Rule 2). They then progressed to a point where they could take account of either weight or distance providing that one of these was the same on both sides of the balance (Rule 3). Siegler found that even 17-year-olds were still using this latter rule much of the time even when they had learned about balance scales during science lessons. Very few children were able to take account of weight and distance simultaneously as is required to solve the most difficult balance scale problems (Rule 4).

Interestingly, Siegler discovered that a major factor in the inability of the 17-year-olds to solve the balance scale problem was that examples they had worked on in class were subtly different from the version used in the experiment:

> A later conversation with a science teacher in the school proved revealing. The teacher pointed out the balance scale in the experiment was an arm balance, whereas the balance scale used in the classroom was a pan balance, in which pans with varying amounts of weight could be suspended from hooks at varying distances from the fulcrum. Retesting a few students indicated that they indeed could solve comparable problems presented on the pan balance! This limited generalization is, unfortunately, the rule rather than the exception in problem solving. (Siegler & Alibali, 2005)

The students' failure to generalise performance across tasks highlights an important issue for studying development. In making claims about children's ability to complete a task successfully, it is important to know how general a particular ability actually is. Is it limited to a single task, to a set of similar tasks or does it extend across a range of dissimilar tasks? Siegler's observations illustrate that very specific characteristics of a particular task can have a significant effect on children's performance. This is an issue that we return to in Chapter 2.

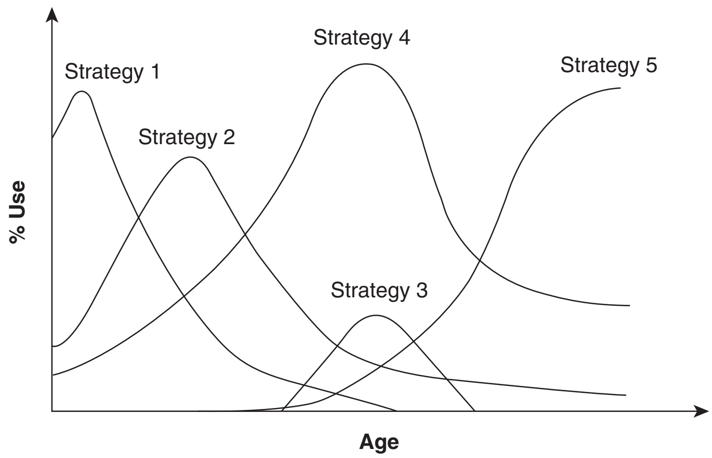


Figure 1.5 *Siegler's overlapping waves modal of cognitive development;* from sieglar Alibali, 2005: 98

Another key feature of Siegler's approach to thinking about developmental change is the idea that children can have, at any one time, a number of different ways of thinking about a particular problem. Siegler argues that children's varied ways of thinking about the same task compete with each other so that, over time, the more advanced ways are used with increasing frequency and the less advanced ways are used less frequently. In other words, children have alternative strategies for solving problems. With experience, strategies that prove effective are used more while other, less effective, strategies disappear. Figure 1.5 illustrates what Siegler describes as an overlapping waves model of development.

You will see in Siegler's model the kind of developmental trajectories noted in the previous section on non-linear dynamics. The different strategies all have a non-linear time course with the most typical pattern being an increase over time followed by decrease. The interesting thing about the model is that it depicts multiple strategies, each with its own time course.

This kind of model is good at explaining variational change since, at any one point in time, children may have several different strategies available. As Siegler notes:

> Children's thinking is far more variable than has usually been recognised. This variability is omnipresent, occurring at all ages, in all domains, and at all points in learning. The variability is evident not just at the neural and associative levels … but also at the level of strategies, theories and other units of higher level cognition. It is present not only between different people … but also within a single person solving the same problem at two points close in time … (Siegler, 2007)

Consider as an example the strategies that young children use to carry out simple addition (Harris & Butterworth, 2002). Most 5-year-olds can use a variety of strategies for problems such as adding 3 and 4. Sometimes they count from 1 to 3 on the fingers of one hand and then count from 1 to 4 on the fingers of the other hand and then, finally, they count all their fingers to get the total, again counting from 1. At other times, the same children might use their fingers but count in sequence from the first hand to the second. On yet other occasions, they might recall the answer without counting or using fingers. Clearly, the possibility that children may use different strategies in the same task, that can vary from day to day or even from trial to trial, has important implications for experimental testing.

## Training studies

Siegler has been particularly interested in the effects of experience on children's development. In an early study of the balance scale (Siegler, 1976), children aged between 5 and 8 years who used Rule 1 (taking account of weight by ignoring distance) were given systematic feedback on one of three types of problem. In the feedback conditions, they were given a balance scale problem and asked which side would go down. Then the balance lock was released and children were able to see which side went down. One group of children saw only examples which they could already solve using Rule 1. The other two groups saw examples where Rule 1 would make the wrong prediction. One group saw problems that could be solved using Rule 2, that is, the weights on the two sides were equal but the distance from the fulcrum varied. Children in the other group were presented with more difficult problems in which either the weights or the distances from the fulcrum were equal. These kinds of problem can only be solved using Rule 3.

Siegler found that the type of feedback affected children's ability to solve new balance scale problems. Not surprisingly, children who had experienced only problems that could be solved using their existing rule did not show any improvement. Both 5-and 8-year-olds, who were shown Rule 2 problems (in which weight was the same but distance varied), usually advanced to Rule 2. This represents a relatively small advance on Rule 1 so it should be fairly easy for children who use Rule 1.

The behaviour of children who had been exposed to Rule 3 problems varied with age. Rule 3 is considerably more sophisticated than Rule 1 and most of the 5-year-olds did not move on from Rule 1. However, most of the 8-year-olds advanced to Rule 3. Subsequent testing showed that the 5-year-olds were only encoding weight in balance scale problems and were not paying attention to distance from the fulcrum. For this reason, they were unable to develop an understanding of Rule 3 which required them to notice how distance affected the balance of the scale. By contrast, the older children were already paying attention to both weight and distance and so were able to acquire Rule 3 with the right kind of feedback. This illustrates very clearly the interaction between new experience and current developmental state. New experience has its greatest effect when it builds on knowledge that is already in the process of developing – an idea that was first encapsulated in Vygotsky's seminal concept of the 'zone of proximal development' (Vygotsky, 1961). This idea has important implications for the design of training studies. Training is most likely to produce an effect if children can readily relate their new experience to what they already know.

## Variation across tasks

Another important aspect of variation in strategy is that children may use different strategies in tasks that are only slightly different. We have already seen, in the case of the balance scale, that children may fail to generalise from one version of a task to another. Other variations in the way that a task is presented can also have an effect on children's performance.

A classic study (Bryant & Kopytnyska, 1976) compared children's use of measurement in a standard Piagetian task with measurement in a very similar task. In the standard Piagetian task, children are shown a tower of bricks standing on a high table. Children are asked to build another tower of the same height on a table that is 90 cm lower. Since the reference tower is not at the same level as the one that the children build, a direct visual comparison of height is not possible; and it is also not possible to simply count the number of bricks required as the two towers use bricks of different sizes. The way to succeed in the task is to measure the reference tower so that the constructed tower can be built to exactly the same height. A stick of the same height as the reference tower is made available for this purpose.

Piaget (Piaget, Inhelder, & Sizeminska, 1960) found that children of 5 and 6 years were reluctant to use the stick as a way of making a comparison and relied, instead, on making a direct – and unsuccessful – comparison between the height of the two towers. At this age they were often very confident about their ability to make a purely visual judgement about the height of the two towers as Piaget's detailed descriptions of the children's responses illustrate. Here is the reaction of a boy, aged 5;3:

> Looks at the model and arranges his bricks differently while making his tower the same height. Now and again he checks on his progress.
>
> [*Experimenter*] 'Is it the same height?'
> [*Child*] 'Yes.'
> [*Experimenter*] 'How do you know?'
> [*Child*] 'By looking at the blocks.'

[*Experimenter*] 'What if I told you it isn't as high?'
[*Child*] 'I can see it's the same.' He adjusts a crooked block without altering the height of the tower.
[*Experimenter*] 'Can you think of a trick to see if it's the same height?'
[*Child*] 'No, I tell you it's right!' (in a peremptory tone).

(Piaget et al., 1960)

Piaget's original observations were confirmed by Bryant and Kopytnyska (1976). However, they found that children who did not spontaneously measure the height of the two towers were much more likely to use a measuring stick when it was clear that a direct visual comparison of length was not possible. In their novel task, children were given two blocks of wood with a hole drilled into the top. The children were asked to find out whether the two holes were of similar or different depth and, if the latter, which hole was deeper. The clever thing about the Bryant and Kopytnyska task was that the relative depth of the two holes could not be determined just from looking into them. Confronted with a task in which direct visual comparison was clearly not possible, children did use the stick to measure and compare the depth of the two holes.

There are many other instances of research showing that children can use a more sophisticated strategy to solve a task when they are supported in doing so by the way a task is structured. When and why children use one strategy rather than another is an important issue for any account of developmental change. Understanding factors that can inhibit and facilitate solutions often provides an important insight into the specific aspects of ability that are in the process of development and into the wider question of why developmental change occurs. See, for example, Bryant's discussion of whether it is conflicting or converging outcomes that lead children to advance to a more sophisticated understanding of the use of measurement (Bryant, 1982).

## Investigating developmental change

So far in this chapter we have considered the different patterns that may appear in developmental change. We have seen that change may be gradual or abrupt, linear or non-linear. We have also seen that there are likely to be large differences both between individuals and even within the same individual tested on different occasions. There are also likely to be differences in the way that children respond to particular tasks. Even small differences in the structure or context of an experimental task can affect performance and, as we saw in the examples of the balance scale and measurement tasks, children may be able to solve problems involving one task but not be able to solve comparable problems involving a very similar task that varies in some critical detail.

There are several principles of good experimental design that emerge from these general observations about the nature of developmental change. Perhaps the most important is that the best studies make use of converging evidence. In other words, they use a number of different ways to assess children's performance and then look for overall consistencies in behaviour.

Another important principle is that good studies of development should enable the study of individual differences. This does not mean that children should only be studied on an individual basis. Indeed, it could be argued that data on an individual child may tell us very little about general patterns of development. What is important, however, is to strike a balance between studying both transformational and variational change. A good study, or series of studies, should reveal both how the abilities of children at different ages and stages of development change and how much individual variation there is in children's behaviour at a given point in development.