Chapter 3: Representation in the early years

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Contents

1 Introduction

A central problem for developmental psychologists is that thinking processes cannot be observed directly. They must be inferred by observing what infants do in their normal relations with the world and using this as evidence of their understanding. In practice, this natural observation is supplemented by research which presents children of all ages with scenarios carefully designed to answer questions about the form and limits of this understanding. This is not always an easy task. The purpose of this chapter is to describe current understandings, derived from research, of the origins and development of children's thinking from birth to 5 years of age. It will show, first, how imaginative investigators can be and, second, how rarely unambiguous evidence is obtained.

Mental representations form the basis for all thought. They can be understood as the internal 'depictions' of objects, events, people and interactions that we experience or imagine. Through the course of this chapter we will explore how information coming through the senses into the brain is processed to create representations, and how these are used for processes such as thinking, decision making and action. It is important to note that mental representations are not just a way of internalising aspects of the world, they are also a set of processes that make use of that information to direct all aspects of our behaviour. It is also important to realise that although words like 'depictions' are used to talk about how our brains store information, what actually happens is nothing at all like the storing of digital photographs on a memory card. How information is represented in the brain remains an open question, but the closest approximation researchers have today is 'neural networks', in the form of computer simulations of brain cells (**neurons**) and their connections (axons) which change in activation levels as successive inputs are fed into the network. In these simulations, the inputs (equivalent to perceptions) modify the pattern of activation levels, so it is this pattern which is the representation of the inputs.

There have been long-standing issues discussed within psychology, between a view that mental abilities are learned by children from their environment (an empiricist position) and a view that children are born with innate capacities already in place (a more **nativist** position). This chapter will examine some of the experimental evidence that has been used to support each side of the debate as it progresses. However, few theorists today would argue for a pure learning or purely innate account of representational development. Sixty years of research in a related field, artificial intelligence, has shown clearly that some precursors that direct attention, generate structure and enable learning are necessary for any system to make sense of incoming information. Current theories about the development of mental representations in young children now focus on the degree to which innate mechanisms and environmental forces each contribute and interact to shape early thinking. However, it is important to understand the basis for each side of the argument in order to appreciate how they are used in current theory.

This chapter aims to address three primary questions. How do we:

- come to form mental representations?
- develop the use of mental representations?
- become able to reflect on our own and others' mental representations?

Summary of Section 1

- Because thinking cannot be directly observed, and because very young children cannot speak about their thinking, researchers have had to develop special methods to investigate this topic.
- The term 'representation' refers to the storage and use of information inside the brain.
- It is important to realise that in no sense are there any pictures or other like-for-like images of external objects and events anywhere inside the brain.
- Current theories about the development of representational abilities in young children consider innate and environmental factors, as well as how these interact.

2 How do we come to form mental representations?

2.1 What is a mental representation?

Mental representations are internal depictions of information that the mind can manipulate (Berk, 2007). However, the word 'mental representation' does not only refer to the *content* of the representation. In order to think about a thing, individuals must not only represent it in their mind but then they also need to use that representation in some way. The term 'mental representation' is used by psychologists not just to refer to *what* is represented but also to the mental processes that make use of such a representation. For instance, an individual may represent an object that is moving towards them because they want to catch it. In this case they must represent the shape, size, speed and direction of the object's movement in relation to their own position, and calculate how they would need to move and shape their body in order to intersect with the object in such a way that would make catching it possible.

Mental representations are the result of complex organisational processes. A continuous stream of information from the outside world is received through our senses (sight, hearing, touch, taste and smell, as well as our sense of our own body's movements and postures) and we interpret that information through perception. *Perception* is the organisation, identification, and interpretation of sensory information in order to represent and understand the environment. Figure 1 outlines the different processes that occur when the brain makes sense of information from the external world.

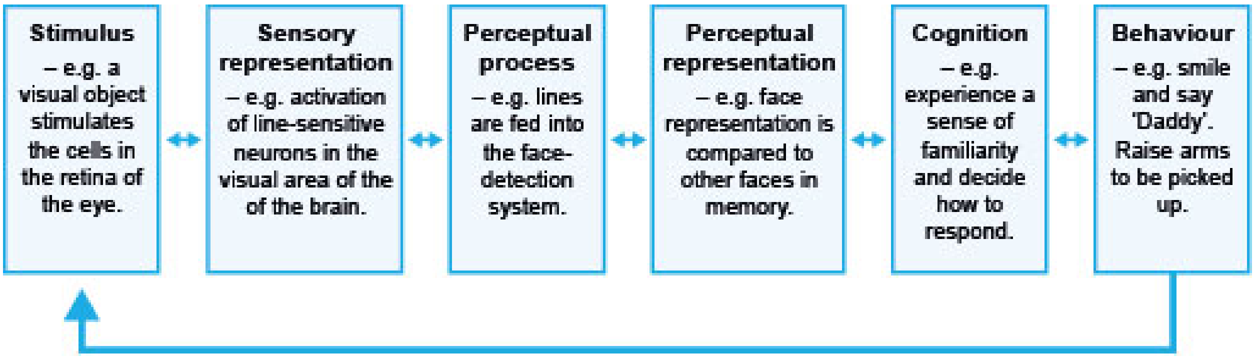

Figure 1 Levels of representations and processing (adapted from Schacter et al., 2012, p. 424)

1 **Stimulus:** First the senses receive the information – this might take the form of an object coming into view and stimulating areas of the eye, which then transmits details about the object to the brain.
2 **Sensory representation:** These details are organised into a sensory representation, in the visual area of the brain, which might include aspects of the object such as its size, colour and orientation.
3 **Perceptual process:** Once a simple sensory representation has been formed it is fed into a perceptual process to determine what the object is and how to respond to it. For instance, at this stage in the process your brain might recognise the initial visual stimulation as a face.
4 **Perceptual representation:** This stage ensures that a perceptual representation is formed in the appropriate area of the brain for thinking about faces. The perceptual representation is more advanced than the sensory representation in that it pulls together all the details transmitted from the eyes. For instance, at this stage the brain might compare the object with other, similar objects already stored there.
5 **Cognition:** Once the perceptual representation has been formed, the individual is in a position to think about the object and decide how to react to it, a process referred to as 'cognition'.
6 **Behaviour:** Perceptual representations and cognition are primarily used to guide the individual's physical interactions with the world. Because researchers do not have direct access to the thoughts and feelings of babies and young children, much of the research into children's representational development has to be based on observations of their behaviour. For instance, young children do not usually greet strange male adults with smiles and gestures to be picked up, so if a particular child responds like this when greeting her father, it suggests that at a representational level she is capable of distinguishing between her father and other males.

You'll note from the diagram that the arrows point in both directions. This is because representation, processing and behaviour are not successive steps in a simple linear process. The networks of the brain that make up this system pass messages in both directions – for instance, what we expect about a situation (cognition stage) can affect what we actually perceive and what information we include in our internal model (perceptual representation stage). The senses do not simply pick up all the information in any given context either. Where our eyes point, for instance, is driven by processes higher up the chain that decide what we direct our attention to. Processing in the two directions are sometimes referred to as 'bottom-up' and 'top-down' processing. **Bottom-up**

processing refers to information from the senses coming up through the system and **top-down processing** refers to higher-level expectations, concepts and categories (see Box 1) coming down through the system to influence what and how the information is processed.

Box 1: Categories and concepts

As adults, an important part of making sense of the world is seeing links between similar experiences and grouping them together. Through this grouping we become able to structure our mental world and form concepts and categories. For adults, much of our categorisation is done through language. Faced with an object that looks like a fish but which breaths air (a dolphin), we will know what category it fits into after being told that it is a mammal. From this we can infer that it will also be able to regulate its own temperature and, if it is female, give birth to live young and have mammary glands. But how do infants, before they use language, come to group their experiences – is each successive experience totally new or do they begin to register similarities among repeated experiences of the same kinds of thing? Research shows that 3–4-month-old infants do indeed have the capacity to group experiences together to form mental categories. Initially these categories seem to be based primarily on external perceptual features such as an object's colour or shape (e.g. red things or round things might be grouped together). Mandler (1997) refers to these as 'perceptual categories'. However, older infants come increasingly to use less obvious features to group things such as what objects are for (e.g. red, round apples as being different to red, round balls because balls are for throwing and apples are for eating). Mandler refers to these as 'conceptual categories'. One important thing to note here is that category formation is a fundamental part of thinking, and that very young infants seem to be capable of it, even though they do not have access to the wealth of category cues that adults receive from language.

Activity 1 Constructing mental representations

Allow about 5 minutes

This activity will help you to appreciate that perception is not a direct mapping of the world onto the brain.

The brain makes sense of (often insufficient or confused) information coming from the senses, which is then processed in different areas of the brain – and reconstructed based on expectations about how the world should behave – to create the experience of perceiving it directly.

Look at the image below. If you have not seen this particular image before, how long does it take you to see what the image is of? Why do you think it's hard to see immediately? Why do you think you can make sense of it at all?

Figure 2 Figure-ground segmentation illusion

Comment

The image is just a series of light and dark patches and the dalmation is camouflaged amongst them with no clear outline to distinguish it from the background. This is why it can take a little while for you to see what the picture is of. The fact that we can see the dalmation at all is because our perceptual processes, responsible for making sense of confusing sensory input, impose meaning onto what we are seeing by looking for patterns among the spots and concluding, on the basis of how the spots are grouped, that the most likely interpretation is that this picture is of a dalmation on a black and white background. Once your brain has made this decision it is very hard to go back to not seeing the dalmation. Note that it is not your eyes that are coming to this conclusion, your eyes are simply transmitting the confusing information to your brain. It is your brain that organises the information into an internal representation which gives structure to the scene and allows you to think about it.

2.2 Jean Piaget's constructivist theory

Traditionally, it was thought that children represented the world in the same way as adults but simply lacked the experience to respond to it in as sophisticated a manner. The advent of **behaviourism** in the early twentieth century moved the focus to only those behaviours that could be observed and measured, ignoring mental events all together. From the behaviourist perspective, development occurred through the passive accumulation of associations between events and the probability of them being paired with rewards or punishments.

Jean Piaget (1896–1980), one of the forefathers of developmental psychology, disagreed with the idea that children are simply passive recipients of learning. Like behaviourists he believed that infants are born without representational ability but he theorised that they are active participants in developing this capacity. He proposed that children are born equipped with the motivation to interact physically with the world, to construct their own knowledge about it, and to internalise those interactions into increasingly complex and abstract representations. He developed a comprehensive theory of how children's thinking developed from birth to adolescence. He observed that before they are able to perform correctly on tasks that involve thinking, their errors are nevertheless often systematic, and this can give insights into what may be going on inside their minds.

Piaget noted that very young infants fail to search for toys that have gone out of sight. He describes an occasion with his baby daughter, Jacqueline, where each time she reached for a toy he would place it under a blanket in front of her. He observed that although Jacqueline looked distressed, she failed to raise the blanket to retrieve the toy, even when he had her hold it through the blanket and repeatedly revealed it before hiding it again. Through carefully documented observations such as these, Piaget concluded that infants lack an understanding of **object permanence**. As adults, we are committed to the idea that objects continue to exist even when they have gone out of sight. In contrast, for infants, out of sight seems to literally mean out of mind.

Figure 3 Infants act as though an object that has gone out of sight has ceased to exist

The important thing to note here is that Piaget believed that young infants were *incapable* of forming mental representations and failed to do so in any really useful way until around 18 months of age. For Piaget, representations of an enduring, permanent world arose slowly through experience of repeated actions and the observation of their effects. However, in contrast to behaviourism, Piaget believed that infants were equipped with an innate set of capacities that enabled them to actively interact with the world in order to construct representations. His theory describes cognitive development as a linear sequence of cognitive steps toward maturity, which all typically developing children achieve at predictable ages.

2.3 The performance–competence problem

One criticism of Piaget's work is that it could underestimate the representational abilities of very young infants. Being able to demonstrate any such competence relies on the child's ability to not just form mental representations but also to use them to guide their physical interaction with the world – a much more complex process. It is possible that Jacqueline did have object permanence and *could* represent the toy that had been placed out of sight but lacked the ability to co-ordinate her actions in order to retrieve it. For instance, Hood and Willatts (1986) showed that, long before they could search for a hidden object under a cover, infants would reach for objects that had gone out of sight because a room became dark. Evidence such as this led researchers to develop more sophisticated ways of measuring infants' representations by focusing on behaviours that infants were more proficient at – sucking, staring and getting bored.

Research summary 1: Infants represent objects *and* their properties

A seminal example of this work was conducted by Renee Baillargeon et al. (1985). Their method rested on the fact that when infants grow bored of something (become 'habituated' to it) they look away and when they are interested in something they continue to look at it. Researchers use this principle to explore what surprises infants – what violates their expectations – and infer from this what representations they already have about the world. Baillargeon et al. habituated a number of infants to a drawbridge that swung back and forth 180 degrees. Once they became bored and looked away (habituated), Baillargeon then showed them that she was placing a block behind the drawbridge. Next, she repeated the display so that half of the infants saw the drawbridge fall part-way and be stopped by the block (the possible event) and the other half saw the same display to which they had previously grown bored – the drawbridge falling flat against the table (an impossible event, as it would have had to travel *through* the solid block).

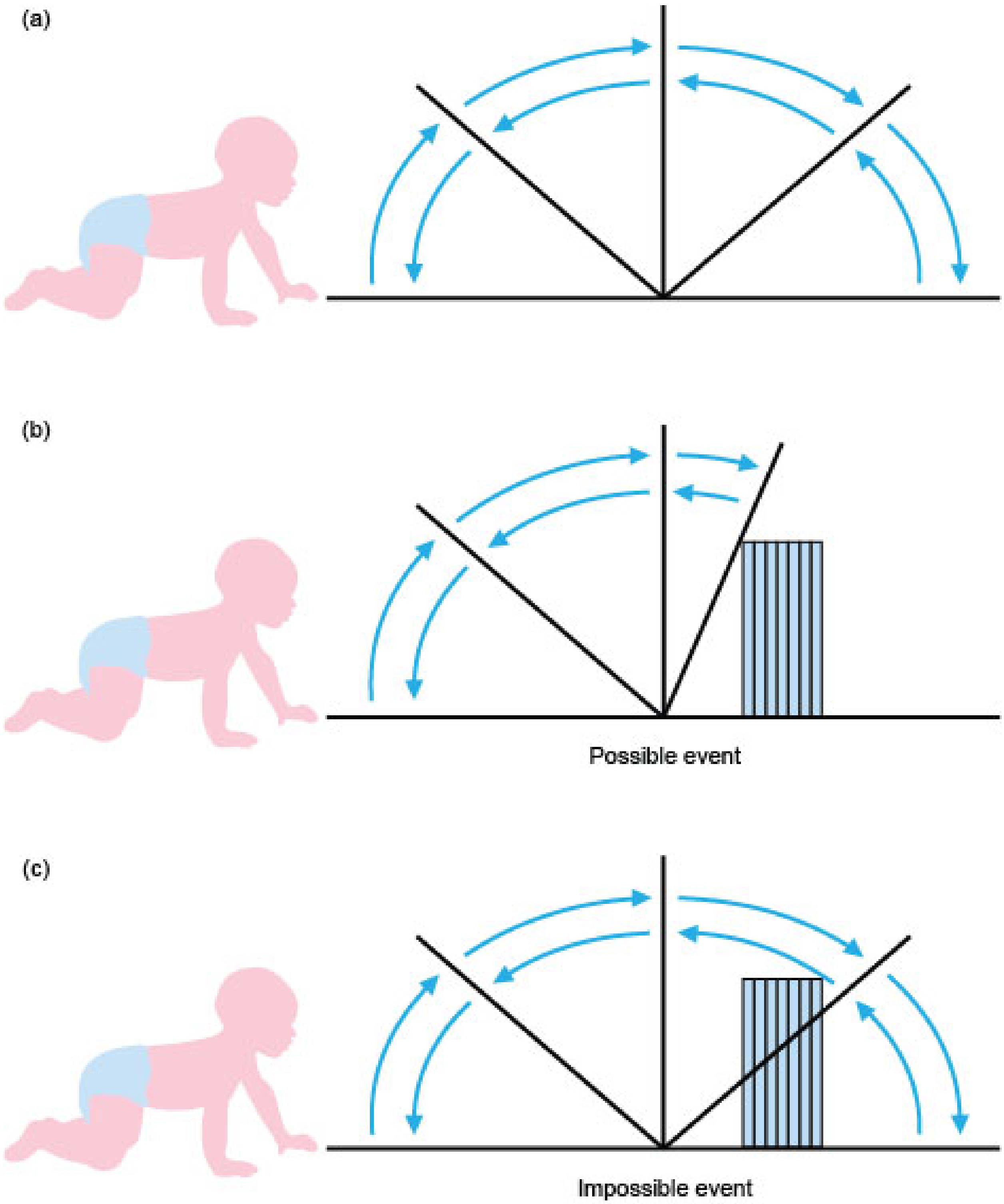

Figure 4 Baillargeon et al. (1985) drawbridge experiment

They found that infants at 5 months of age (and many 3-month-olds) looked significantly longer at the impossible event than they did at the possible event. This suggested to the researchers that the infants, like adults, expected the solid block to stop the drawbridge and were surprised when it did not. They inferred that infants by 5 months of age not only represent the block when it is out of sight (behind the drawbridge), but also represent properties about the block such as the effect that its solidity will have on the falling drawbridge. This is much earlier than Piaget predicted infants would be capable of these sorts of representation.

2.4 Core knowledge theories

The drawbridge study is one among literally thousands of experiments measuring young infants' looking time at unexpected events. These generally support the conclusion that even very young infants, from around 2–4 months of age, are in fact able to represent objects that have gone out of sight and have relatively sophisticated expectations about how they should behave. On this basis, Spelke et al. (1992) have proposed that infants may be born with certain 'core knowledge' concepts about the physical world, which shape their expectations of how objects and events, and their properties, ought to behave. Based on looking-time studies like the one described in Section 2.3, Spelke proposes at least three innate (i.e. present at birth) expectations about how objects behave when out of sight:

> **Continuity** – that objects travel along continuous paths and do not pop in and out of existence.
>
> **Cohesion** – that objects maintain consistent boundaries as they move.
>
> **Solidity** – that solid objects cannot pass through each other.

For instance, 10-week-olds were habituated to a ball being rolled behind a screen, as illustrated in Figure 5. The screen was then raised to reveal the ball stopped at the end of the track. A blue obstacle, visible over the top of the screen, was then placed in the way of the ball. The ball was rolled and the screen was raised again to reveal the ball stopped by the obstacle (possible trials) or once again at the end of the track (impossible trials) as though it had travelled *through* the obstacle. Despite the end-state being the same as on the habituation trials, 10-week-olds looked longer at impossible trials than they did at possible trials. This suggests that the ball appearing to have travelled through the obstacle is somehow contrary to their expectations. The researchers interpret this as evidence that infants as young as 10 weeks can not only represent the ball when it has gone out of sight but can also maintain expectations about its position and interactions with other physical objects. Just as in the Baillargeon study previously described, this study reinforces the view that even young infants have expectations (representations) about the properties of objects and events in the world.

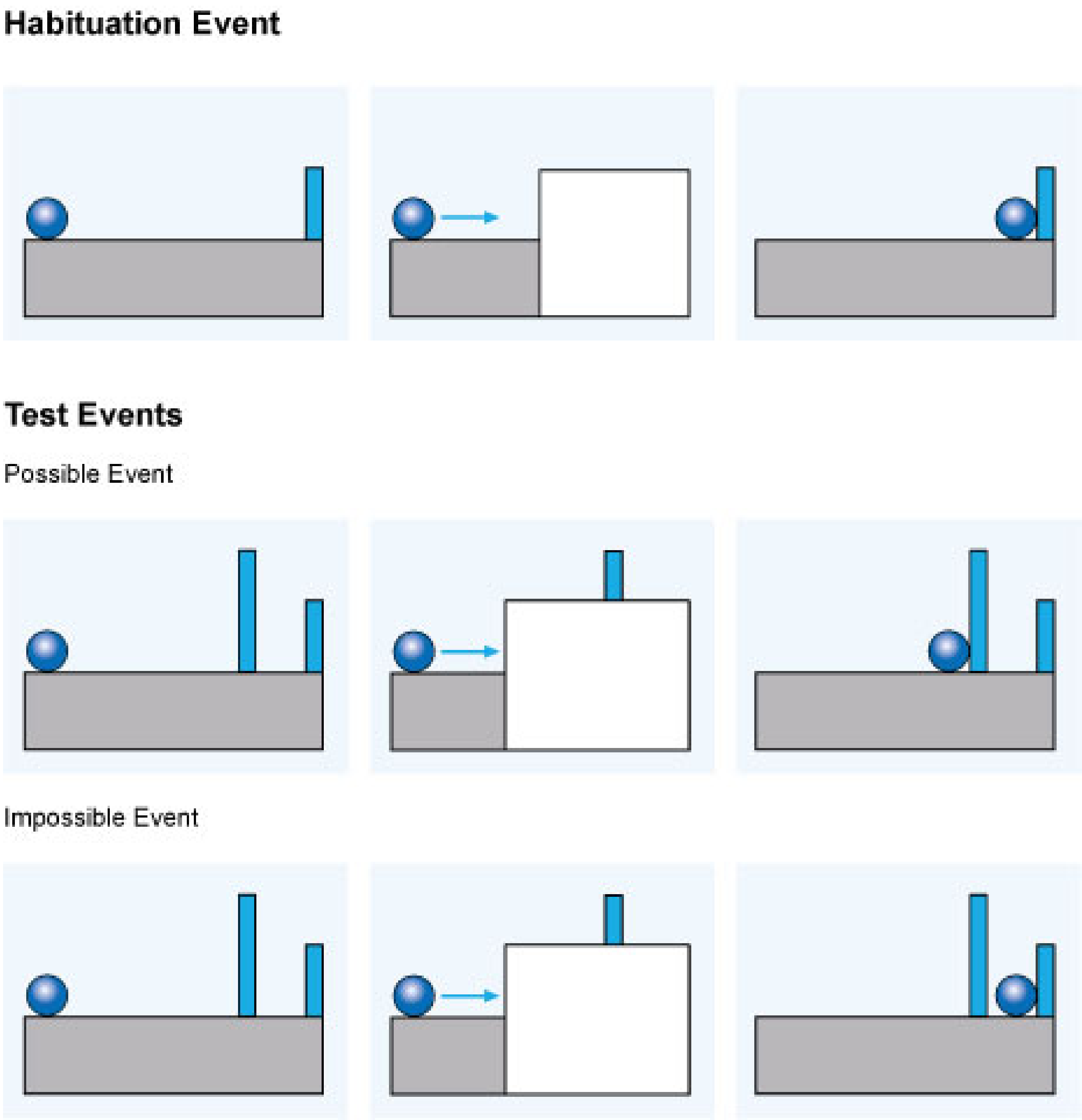

Figure 5 Spelke and colleagues' solidity task (based on Spelke et al., 1992)

Summary of Section 2

- Mental representations are influenced by information coming up through the senses and cognitive expectations coming down through the representational system.
- Rather than a simple remapping of events in the world, representation is a creative, constructive process, influenced by both external stimulation and internal processes.
- Based on infants' search behaviour, Piaget believed that infants become able to form mental representations through extensive physical interactions with the world.

- Based on infants' looking time at impossible events, core-knowledge theorists propose that infants can represent objects that have gone out of sight and are born with a small set of core expectations about how objects should behave.

3 How does the ability to use mental representations develop?

The sea squirt is a marine creature born with a simple brain and tail that enable it to find a place in which to anchor itself (such as a rock or the underside of a boat). It stays attached to this object for the rest of its life and feeds by filtering nutrients from the water passing through it. When it finds its attachment point the sea squirt digests its own brain. This is often used as a metaphor for how important the interaction is between representational brains and actual behaviour and interaction with the world. All of the other functions of the sea squirt (feeding, procreating, etc.) continue virtually automatically because when it doesn't need to move about, it no longer needs a brain to influence its behaviour. It seems then that one of the fundamental purposes of mental representations is to support directed action.

Much of Piaget's theory is based not just on how infants become able to form mental representations, but how they become able to *use* them in increasingly flexible, sophisticated and consistent ways. The processes associated with mental representations are as important as infants' abilities to form them in the first place. In Section 2 of this chapter we saw evidence of dissociation between infants' use of mental representations to guide their expectations – as measured by their gaze in the Baillargeon et al. (1985) study – and their actual behaviour – as measured by their search for hidden objects, such as in the example of Piaget's daughter Jacqueline).

3.1 The A-not-B error

This sort of dissociation between what infants appear to understand (from their responses to looking-time experiments) and their ability to use that understanding to guide action is characteristic of a great deal of developmental research. As part of his extensive observations, Piaget highlighted a common search error that infants make, which he dubbed the 'A-not-B' error (1954). He showed that although infants at 10 months of age will start to search for an object that has been hidden, if it is hidden repeatedly in one covered container or place (location A) and then moved to an adjacent covered place (location B), the majority of babies will consistently search for it in the previous hiding location (A) despite watching it being moved to the new place. This is a very robust phenomenon and has been repeated thousands of times. Piaget took this error as evidence that although by 10 months of age infants *can* represent objects that have gone out of sight, those representations are very different from those of adults.

Anecdotally, however, Piaget noted that infants often look to the right location even as they are reaching for the wrong one. A number of subsequent studies seemed to support this. For instance, Baillargeon and Graber (1988) have shown that infants look longer if the covers are removed to reveal the toy in a different location from where it was placed, showing that although infants reach for the wrong location they have an expectation that the toy should be where it was hidden. That is, they have represented the actual location of the object and are surprised when it is not there. Hofstadter and Reznick (1996) showed experimentally that infants look to the correct location twice as often as they search there. Perhaps most convincingly, Butterworth (1977) showed that infants would search for the toy in the previously correct location even if the covers over the hiding places were transparent and the infant could clearly see where the toy was. This last task removes any need for infants to represent the hidden object at all and yet they still show errors. These apparent dissociations between where infants look (their ability to mentally represent hidden objects) and where they search (their ability to use those mental representations) have raised important questions about how we interpret children's looking time and behaviour.

3.2 Why do infants look so clever and toddlers look so dumb?

The argument made by core-knowledge theorists is that infants are able to represent objects and their interactions while out of sight but can't express this knowledge because they are not yet able to appropriately control their actions. However, core-knowledge theories struggle to explain why the knowledge evident on infant looking-time experiments is often absent in much older children's search responses. Pre-schoolers by 2–3 years of age should have no difficulty co-ordinating action plans, representing hidden objects or manipulating covers, and so we would expect the knowledge evident from infant looking-time experiments to guide correct search. Spelke's solidity experiment, described in Section 2.4, indicates that infants from 2 months of age can represent the solidity of objects that have gone out of sight and make predictions about their interactions. Is this knowledge evident when tested with much older children?

To examine this, a number of researchers have adapted the solidity experiment to make it appropriate for use with older children. This version makes use of four doors instead of a single screen. A toy is repeatedly rolled down the slope to come out the other side; then an obstacle, visible over the top of the doors, is placed in the way of the toy. The toy is rolled once again and the child is asked to come and open the correct door to find it (the obstacle is moved between trials so that the correct search location changes each time). This is illustrated in Figure 6 below. Remember from Section 2.4 that the looking-time results suggest that infants from 2 months of age understand that solid objects cannot pass through other solid objects (Spelke et al., 1992) but lack the ability to demonstrate that knowledge behaviourally. As such, we would predict that much older children would have little difficulty using these representations to guide their correct search for the toy.

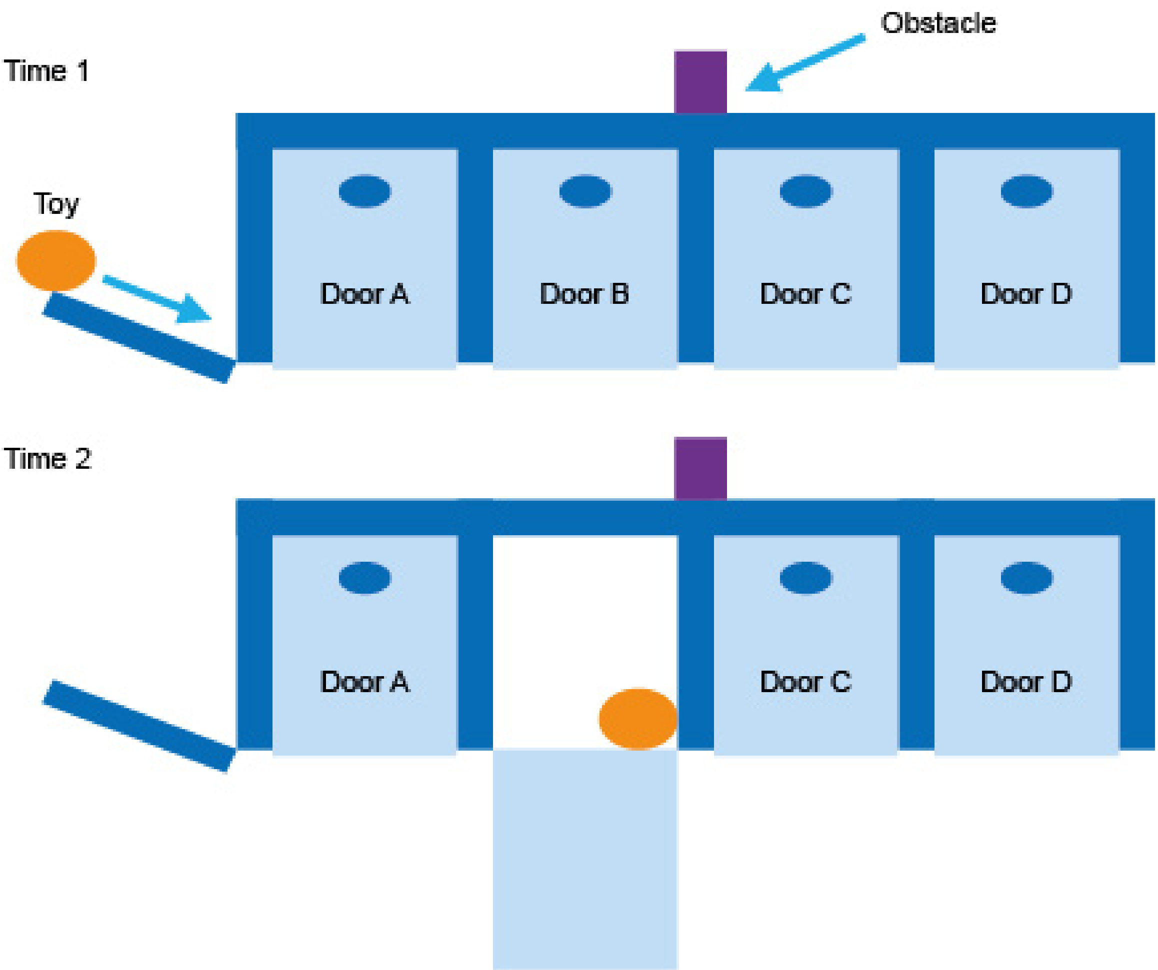

Figure 6 The four-door solidity experiment; Time 1: the toy is rolled behind the screen and is stopped by the visible obstacle; Time 2: the correct location to search for the toy is behind door B, where it has been stopped by the visible obstacle between doors B and C

However, this is not the case. Over several repetitions, children as old as 3 years of age did not consistently or reliably pass this task. Interestingly, if they were presented with a display where the experimenter opens the door to reveal the ball on the wrong side of the wall (as if it has passed through the solid barrier), preschoolers, like infants, look longer and express surprise (Hood et al., 2003). So it is not that the knowledge apparent from the looking-time experiments with infants is somehow lost by age 3. Rather, infants are failing the search tasks because of something other than simply being unable to control their actions.

3.3 Executive functions and frontal lobe development

One possibility to explain infants' failures on the A-not-B task and pre-school children's failure on the four-door task is that simply representing an object that is out of sight is not sufficient to guide appropriate action. A whole range of other processes might be needed. For instance, breakdowns in a process called 'inhibition' – the ability to suppress an inappropriate action or thought – have been well documented in adult patients suffering from brain damage. Lesions to the frontal lobes of the brain, especially in an area known as the dorsolateral prefrontal cortex (DLPFC) (see Figure 7), are associated with impairments in planning and abstract thought.

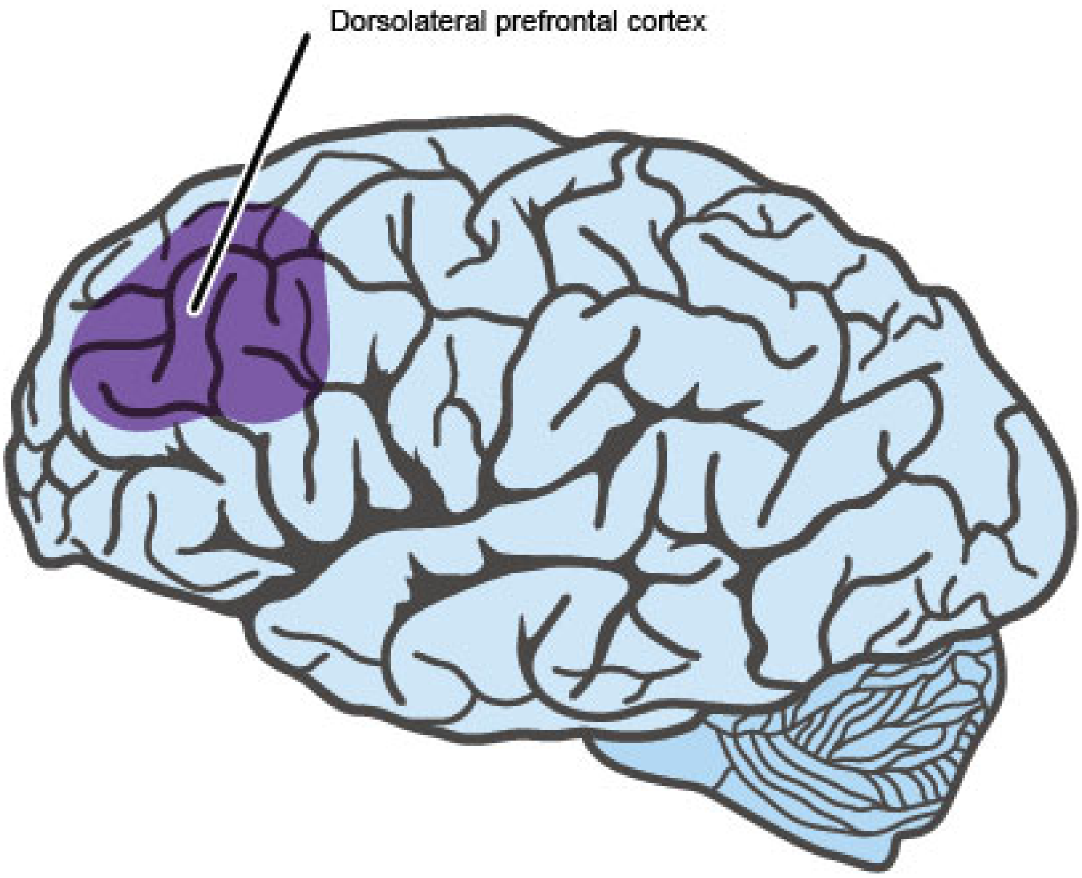

Figure 7 The dorsolateral prefrontal cortex of the human brain (the front of the brain, behind the forehead)

The frontal lobes in humans have one of the longest developmental time courses of any part of the brain, not reaching full maturity until a person is in their mid-twenties (Huttenlocher, 1979). This has led a number of developmental psychologists to propose that search errors in children could be attributed to immature frontal lobe functioning.

One way to understand the relationship between cognitive development and the prefrontal cortex is to chart advances in cognitive abilities and to try and relate these to observed changes in the prefrontal cortex. Does the emergence of a particular ability happen at the same age as an observed change in brain structure? Such correlation doesn't necessarily mean the two are related, but does suggest that the association bears further investigation.

An example of this is the work of Diamond and Goldman-Rakic (1989). They noted that infant human and non-human primates make similar errors on search tasks. For instance, if presented with a treat behind a clear screen, both will bang against the screen trying to reach it while adult human and non-human primates will reach around the screen. To examine directly whether the DLPFC was implicated in success on Piaget's A-not-B task, they trained a group of rhesus monkeys to pass the task and then lesioned (surgically damaged) their DLPFC. They observed that these monkeys reverted back to A-not-B errors, like infants, while those with lesions to other parts of their brain did not. Diamond and Goldman-Rakic also argued that the maturation of the prefrontal cortex between 6 and 12 months of age accounts for a number of transitions observed in infant behaviour on object permanence and object retrieval tasks. Diamond (1991) concludes that:

> Cognitive development can be conceived of, not only as the progressive acquisition of knowledge, but also as the enhanced inhibition of reactions that get in the way of demonstrating knowledge that is already present.
>
> (Diamond, 1991, p. 67)

Activity 2 Slips of action

Allow about 10 minutes

This activity will help you to appreciate the role that inhibition plays even in adult thinking.

Identify examples from your own experience of '**slips of action**', when something that you meant to do was overridden by automatic, habitual behaviour that had failed to be inhibited. One example might be dialling a familiar telephone number only to realise when the person answers that you had meant to telephone someone else.

Comment

Here are some examples:

- Finding that you have accidentally started to take a route to work, a well-rehearsed journey, when you had intended to drive somewhere else.
- Writing the previous year's date on a document.
- Forgetting what you have come into a room to retrieve.
- Putting milk into tea for someone who does not take milk.

Everyday mistakes such as these arise from highly automated behaviours taking over from a conscious plan to do something else. These are examples of momentary failures of **executive function**. The mistakes that children make in the game 'Simon says' also result from strongly automated actions (copying the leader repeatedly) overriding conscious planning. A term often used for such strongly established behaviours is 'pre-potent responses'.

Failures of inhibition have also been seen as an explanation for pre-schoolers' errors on the four-door solidity task. Baker et al. (2011) analysed the sorts of errors that young children made and found that one common error was to return to the door that had been correct on a previous trial (before the wall was moved). The authors suggest that, as on the A-not-B task, inhibiting a previously correct (pre-potent) response may be difficult for children under 3 years of age. So, while they are capable of representing the object that has gone out of sight and has been stopped by the visible obstacle, they are not yet able to inhibit alternative, inappropriate search responses.

Research summary 2: Inhibition and education

The 'Stanford marshmallow experiment', conducted by Mischel et al. in 1972, presented children aged 4–6 years with a treat (such as a marshmallow) and told them that if they could stop themselves eating it until the experimenter returned to the room (about 15 minutes later) they would be rewarded with two treats. Older children were more likely to show self-restraint. However, regardless of age, subsequent follow-on studies revealed that there was a relationship between the length of time each child waited before eating the treat, and important life outcomes such as educational attainment and SAT scores in adolescence. That is, those who could better inhibit their impulse to eat the marshmallow also tended to do better many years later on a range of different tasks.

Given the apparent importance of inhibition in education, for example, in being able to sustain concentration on a learning task, several programmes have been developed to help children to build their inhibitory capacity and self-regulation skills. For instance, Diamond et al. (2007) have developed a preschool curriculum called 'Tools of the Mind' that concentrates 80 per cent of the typical day's activities specifically on tasks that build these skills. They found that compared to matched groups who do not receive this training, the children on this curriculum subsequently performed better on a range of different tasks measuring their self-regulation and on independent measures of academic performance such as reading development.

A relatively common developmental disorder – Attention Deficit Hyperactivity Disorder (ADHD) – is characterised by poor inhibitory and self-regulation skills. Diamond and Lee (2011) have shown that concentrated practice and repetition of tasks that build these skills, such as meditation, computerised training and martial arts, can all help children suffering from this disorder to achieve significantly better educational outcomes in the long term.

3.4 Natural pedagogy accounts

Another recent theory regarding the sorts of search errors made by infants and young children is that they are actually responding to social cues of the experimenter, which lead them to make mistakes despite having both the representational ability and physical ability to pass the tasks. In an important study that highlighted this interpretation, Topál et al. (2008) repeated the A-not-B task with 10-month-olds, in three different conditions. Typically, during the A-not-B task the infant sits on the mother's lap, facing the two hiding places and the experimenter. Before each trial the experimenter gets the infant's attention by calling their name, making eye contact and waving before placing the toy in one of the hiding places and covering it up. This interaction has always been assumed to be necessary to keep the infant on task. Topál and colleagues compared infants' performance when they conducted the study as it had been before, including all the same social cues (ostensive-communicative version), with a second, non-communicative version where the experimenter did not wave or call the infant's name and did not make eye contact, and a third, non-social version where the experimenter was concealed behind a curtain while moving and hiding the object. This had the astonishing result that success rates for 10-month-olds more than doubled from around only one in five in the ostensive-communicative version to more than one in two in the non-communicative and non-social versions, as shown in Figure 8.

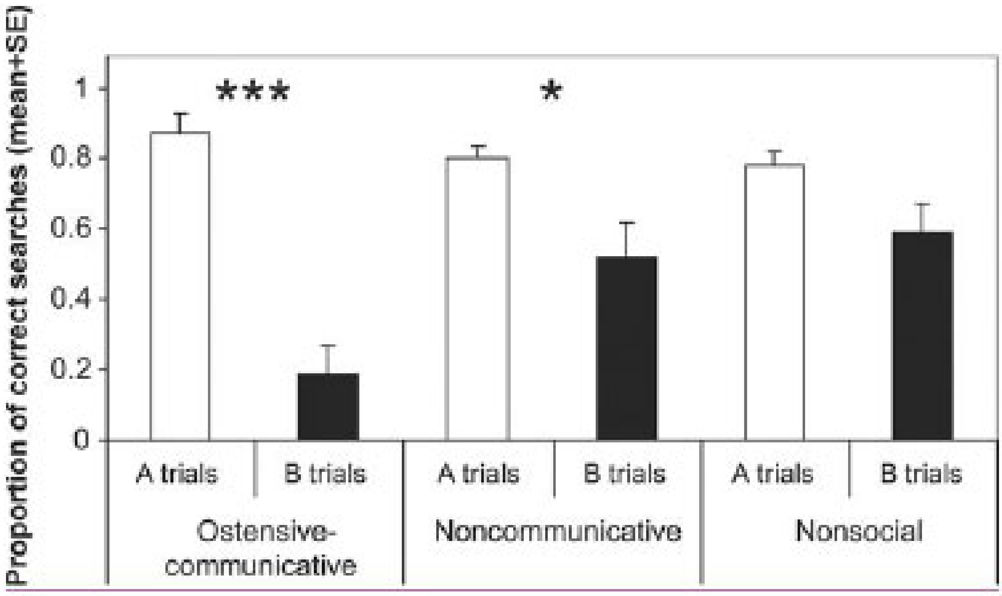

Figure 8 Proportion of correct searches in A- and B-trials as a function of the hiding context

The authors conclude that errors on the A-not-B task might arise not because the infant is struggling to represent the hidden object or inhibit a competing response, but because the constant signalling of the experimenter leads the infant to believe that the point of the game is to search in location A, regardless of where the toy actually is. When the experimenter stops socially interacting, the infant is free to search for the attractive object in the place that she knows it is. This might also explain why infants look to the place they know the toy is but nonetheless reach for the location that was previously correct.

Summary of Section 3

- Piaget believed that infants' failures on the A-not-B task are evidence that infants' object representations are very different from those of adults.
- Core-knowledge theorists base their views on evidence that infants often look to the right location despite searching in the wrong location. They interpret this as evidence that infants *can* represent objects that have gone out of sight, in much the same way as adults.
- However, evidence that much older children fail the four-door task suggests that having a mental representation of the location of an object is not sufficient to correctly guide search, even when physical constraints are outgrown.
- Diamond and colleagues propose that in order to pass the A-not-B task, infants must simultaneously be able to represent the true location of the object *and* inhibit the desire to search at the last location they were rewarded.
- An alternative sociocultural explanation suggests that infants have no difficulty representing the object or searching in the right place but make mistakes on the A-not-B task because of the way they read the experimenter's intention.

4 Reflecting on representations

4.1 Levels of representation

So far we have explored how infants come to form mental representations (Section 2) and how their abilities develop to use mental representations to guide action (Section 3). For simplicity, mental representations have been presented simply as internal states that the individual can access and manipulate but, in fact, the situation is likely to be more complex. Many theorists propose that there are multiple levels of representation, some of which are more consciously accessible than others.

One common distinction between different levels of representation is drawn between those that we can explain in words and those that we struggle to be able to articulate, the ones that we feel as though our body just 'knows'. This distinction is sometimes referred to as 'explicit knowledge' – which can be accessed, explained and reflected on – and 'implicit knowledge' – representations that are unconscious or not available to reflection.

Karmiloff-Smith (1992) has proposed that representational development through early childhood is characterised by infants moving from implicit representations, accumulated through physical interaction with the world, to increasingly explicit forms of representation that can be reflected upon, updated or modified as new experiences and learning are considered. This might sound similar to Piaget's constructivist theory. In fact, Karmiloff-Smith was a student of Piaget's and, like all developmental psychologists, was greatly influenced by his ideas.

However, her theory differs somewhat from Piaget's in that she believes that this redescription of knowledge from implicit to explicit can happen at different rates for different types of information, and at any time-point in development. Thus, very young children may become able to think explicitly and abstractly about one type of experience while persisting in responding implicitly towards another type of experience for some time. She also noted that children will often get worse at a task before they get better (see Research summary 3). This contrasts with Piaget's theory that children will experience cognitive leaps at predictable ages characterised by more mature thinking across all types of problems.

Research summary 3: U-shaped learning curves

Karmiloff-Smith (1984) asked children from 4–9 years of age to balance a series of different blocks on a narrow metal support. Some of these blocks were evenly weighted and balanced at their geometric centre. Others had lead weights hidden inside at one end so that they balanced way off centre. In terms of success, the children of 4 and 8 years old performed significantly better than 6-year-olds, who regularly failed to find the balancing point of the off-centre blocks. That is, the youngest and oldest children appear to pass the task while those in the middle failed.

Examination of the techniques that children in each age group were using revealed interesting differences. The 4-year-olds treated each block as a separate problem, establishing balance through implicit trial and error each time. Karmiloff-Smith suggests that the 6-year-olds, who are failing the task, are doing so because, unlike the 4-year-olds, they have a theory that all objects balance in their geometric centre.

Presented with counter-examples, such as blocks that do not balance in their geometric centre, they assume that their theory is right but that they are doing something wrong, so try repeatedly to balance the blocks more carefully before eventually discarding them as anomalies to the rule. Eight-year-olds, by contrast, have the representational flexibility to utilise the rule of central balance where it works but not in those cases where it doesn't. Note that although their behaviour – passing the task – is the same as that of the 4-year-olds, their underlying representations are very different. This U-shaped pattern of development, in which children appear to get worse at a task before getting better, is seen frequently in developmental studies and argues against a simple linear account of how children's thinking develops.

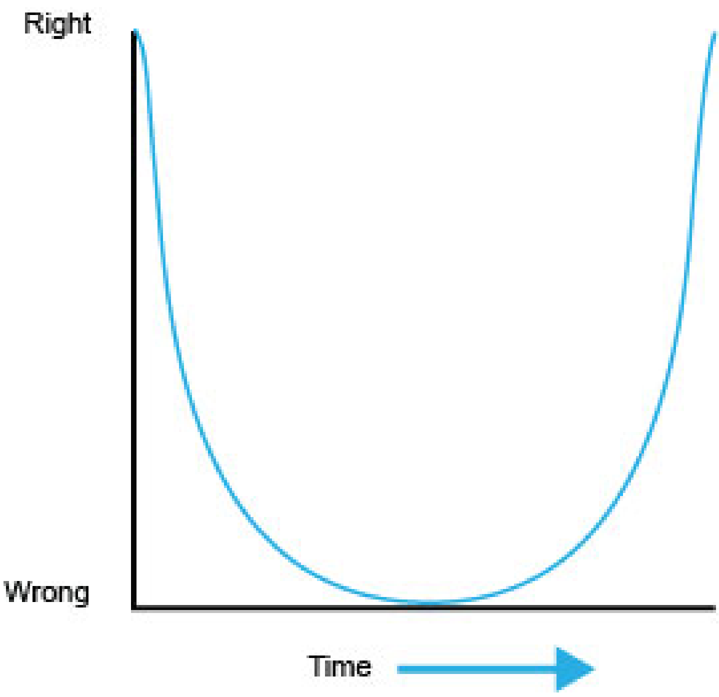

Figure 9 Many developmental advances seem to get worse before they get better

4.2 Meta-representation of others' mental states

Although children's pass rates on different tasks seem to be much more complex than a purely linear theory of cognitive development would suggest, there does appear to be a significant shift in children's thinking between about 3 and 4 years of age. At about this time, children seem to be able to consistently and reliably pass a range of different problems that they previously failed. One suggestion has been that it is at around this age that children develop the ability to *reflect* on their own representations, a process referred to as '**meta-representation**'.

Meta-representation has consequences for all domains of thought but is perhaps most easily described in relation to '**theory of mind**' – the ability to recognise and reason about other people's beliefs and desires, and to understand that they might be different from one's own. Part of this involves the ability to hold multiple representations of a scenario and to move flexibly between them in order to make predictions. Classic tests of theory of mind include **false-belief tasks**. For example, to test their abilities to comprehend false beliefs, children are typically presented with a scenario (Wimmer and Perner, 1983) in which a doll ‘actor’ (Sally) hides a marble in one of two locations and then leaves the room. Subsequently, children watch as a second doll ‘actor’ (Anne) comes into the room and moves the marble from the first location to the second location. Sally re-enters the room and the children are asked to predict where Sally will search for her marble. In order to pass this task, children must hold at least two representations in mind. First, they need to have a true-belief representation of where the marble really is now that it has been moved. At the same time, they must also represent Sally’s false-belief – she thinks the marble is where she left it. Children must correctly attribute the false-belief to Sally (that she will search in the location where she left the marble) rather than their own true-belief (knowing where the marble really is now). Children typically do not begin to pass this task until around 4 years of age.

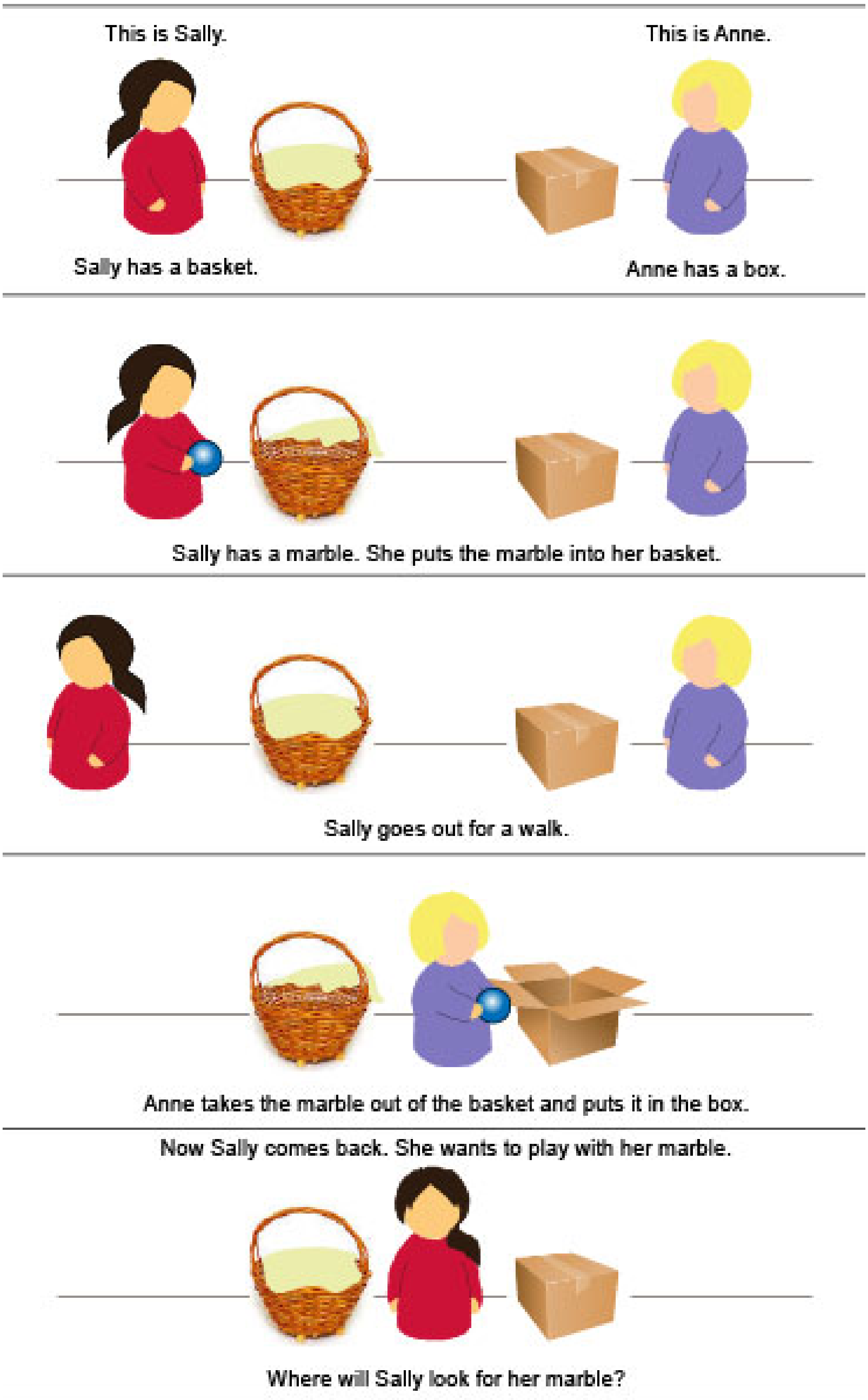

Figure 10 The Sally–Anne task

4.3 Meta-representation of non-mental states

This leap is not limited to reasoning about other people's mental states. The emergence of meta-representational capabilities is likely tied to maturation of the frontal lobes. Thatcher (1992) noted that there was a sharp increase in frontal-lobe development between the ages of 4 and 7 years, which correlates with many of the improvements in children's performance across a range of different tasks, tapping knowledge in different domains. Children around 4 years of age also start to pass a range of other tasks that require them to think about representations. For instance, children start to show a reliable ability to use a map as a representation of real space (Newcombe and Huttenlocher, 2000), they begin to be able to recognise homonyms – words that can mean two different things depending on the context – and they start to show an ability to recognise that ambiguous figures, like the duck–rabbit image (Figure 11), can be seen as two different objects. Children at this stage also begin to reliably distinguish between fantasy and reality. For instance, if you show a 3-year-old a sponge painted to look like a rock, they will generally say that it is both a rock and looks like a rock, or that it is a sponge and looks like a sponge. Not until around 4 years of age do children say that it is a sponge that looks like a rock (Flavell, Flavell and Green, 1983).

Figure 11 Duck–rabbit ambiguous figure

Summary of Section 4

- Mental representations can occur at different levels, which determine how accessible they are to conscious thought and description.
- Karmiloff-Smith (1992) has proposed that cognitive development occurs through a process of representations becoming increasingly explicit.
- Although there are many examples that cognitive development is not linear, there does seem to be a significant leap in children's representational ability at around 4 years of age.

- Some theorists believe this occurs because maturation of the frontal lobes of the brain enables children to become able to compare and reflect upon multiple representations, a process known as meta-representation.

5 Conclusion

This chapter has focused on debate surrounding three main questions:

- When do infants become able to form mental representations?
- When do they become able to use mental representations to guide action?
- When do they become able to reflect upon their representations?

The chapter has used selected studies to illustrate the evidence that different theorists use to support their claims. On the one hand, Piaget claimed that infants were initially incapable of forming mental representations and that cognitive development occurred in a linear, stage-like sequence of increasing flexibility and sophistication. Other theorists have shown that even very young infants do seem capable of mental representation and may even be born with innate concepts that guide their expectations about how objects should behave while out of sight.

Mental representations form the basis for all thought and, thus, the developmental trajectory of children's cognitive ability has implications for all areas of development that you are studying in other parts of this module.

References

Baillargeon, R. and Graber, M. (1988) 'Evidence of location memory in 8-month-old infants in a nonsearch AB task', *Developmental Psychology*, vol. 24, no. 4, pp. 502–11.

Baillargeon, R., Spelke, E. S. and Wasserman, S. (1985) 'Object permanence in five-month-old infants', *Cognition*, vol. 20, no. 3, pp. 191–208.

Baker, S. T., Gjersoe, N. L., Sibielska-Woch, K., Leslie, A. M. and Hood, B. M. (2011) 'Inhibitory control interacts with core knowledge in toddlers' manual search for an occluded object', *Developmental Science*, vol. 14, no. 2, pp. 270–9.

Berk, L. E. (2007) *Development Through the Lifespan*, 4th edn, Boston, MA, Pearson Education.

Butterworth, G. (1977) 'Object disappearance and error in Piaget's stage IV task', *Journal of Experimental Child Psychology*, vol. 23, no. 3, pp. 391–401.

Diamond, A. (1991) 'Neuropsychological insights into the meaning of object concept development', in Carey, S. and Gelman, R. (eds) *The Epigenesis of the Mind: Essays on Biology and Cognition*, Hillsdale, NJ, Lawrence Erlbaum Associates, pp. 67–110.

Diamond, A. and Goldman-Rakic, P. S. (1989) 'Comparison of human infants and rhesus monkeys on Piaget's AB task: evidence for dependence on dorsolateral prefrontal cortex', *Experimental Brain Research*, vol. 74, pp. 24–40.

Diamond, A. and Lee, K. (2011) 'Interventions shown to aid executive function development in children 4 to 12 years old', *Science*, vol. 333, no. 6045, pp. 959–64.

Diamond, A., Barnett, W. S., Thomas, J. and Munro, S. (2007) ‘Preschool program improves cognitive control’, *Science*, vol. 318, no. 5855, pp. 1387–8.

Flavell, J., Flavell, E. and Green, F. (1983) ‘Development of the appearance-reality distinction’, *Cognitive Psychology*, vol. 15, no. 1, pp. 95–120.

Hofstadter, M. and Reznick, J. S. (1996) ‘Response modality affects human infant delayed-response performance’, *Child Development*, vol. 67, no. 2, pp. 646–58.

Hood, B. and Willatts, P. (1986) ‘Reaching in the dark to an object’s remembered position: evidence for object permanence in 5-month-old infants’, *British Journal of Developmental Psychology*, vol. 4, no. 1, pp. 57–65.

Hood, B., Cole-Davies, V. and Dias, M. (2003) ‘Looking and search measures of object knowledge in preschool children’, *Developmental Psychology*, vol. 39, no. 1, pp. 61–70.

Huttenlocher, P. R. (1979) ‘Synaptic density in human frontal cortex — developmental changes and effects of aging’, *Brain Research*, vol. 163, no. 2, pp. 195–205.

Karmiloff-Smith, A. (1984) ‘Children’s problem solving’, in Lamb, M. E., Brown, A. L. and Rogoff, B. (eds) *Advances in Developmental Psychology Volume 3*, Hillsdale, NJ, Lawrence Erlbaum Associates, pp. 39–90.

Karmiloff-Smith, A. (1992) *Beyond Modularity: A Developmental Perspective on Cognitive Science*, Cambridge, MA, MIT Press/Bradford Books.

Mandler, J. M. (1997) ‘Development of categorisation: perceptual and conceptual categories’, in Bremner, G., Slater, A. and Butterworth, G. (eds) *Infant Development: Recent Advances*, Hove, Psychology Press, pp. 163–89.

Mischel, W., Ebbesen, E. B. and Raskoff-Zeiss, A. (1972) ‘Cognitive and attentional mechanisms in delay of gratification’, *Journal of Personality and Social Psychology*, vol. 21, no. 2, pp. 204–18.

Newcombe, N. and Huttenlocher, J. (2000) *Making Space: The Development of Spatial Representation and Reasoning*, Cambridge, MA, MIT Press.

Piaget, J. (1954) *The Construction of Reality in the Child*, New York, Basic Books.

Schacter, D. L., Gilbert, D. T., Wegner, D. M. and Hood, B. M. (2012) *Psychology*, European Edn, Basingstoke, Palgrave Macmillan.

Spelke, E. S., Breinlinger, K., Macomber, J. and Jacobson, K. (1992) ‘Origins of knowledge’, *Psychological Review*, vol. 99, no. 4, pp. 605–32.

Thatcher, R. W. (1992) ‘Cyclic cortical reorganization during early childhood’, *Brain and Cognition*, vol. 20, no. 1, pp. 24–50.

Topál, J., Gergely, G., Miklósi, A., Erdőhegyi, A. and Csibra, G. (2008) ‘Infants’ perseverative search errors are induced by pragmatic misinterpretation’, *Science*, vol. 321, no. 5897, pp. 1831–4.

Wimmer, H. and Perner, J. (1983) ‘Beliefs about beliefs: representation and constraining function of wrong beliefs in young children’s understanding of deception’, *Cognition*, vol. 13, no. 1, pp. 103–28.

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