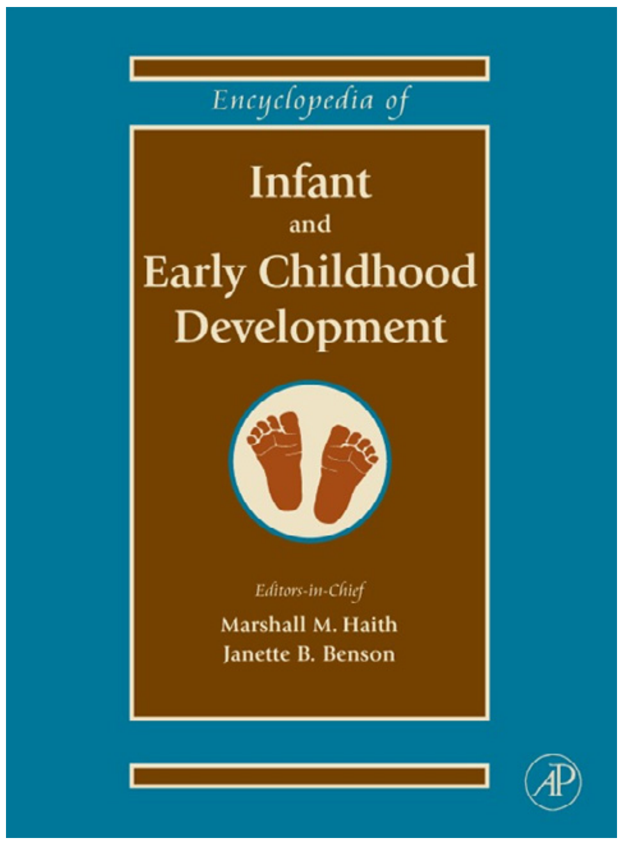


Vallotton C D and Fischer K W, Cognitive Development. In: Encyclopedia of Infant and Early Childhood Development, ed. by Marshall M. Haith and Janette B. Benson. © 2008, Academic Press, San Diego

Cognitive Development

C D Vallotton and K W Fischer, Harvard Graduate School of Education, Cambridge, MA, USA

Glossary

Cardinality – In development of numeracy, the principle that the last number counted in a set represents the size of the set.
Conservation – The awareness that quantity remains the same despite change in appearance.
Décalage – Unevenness in development characterized by level of performance varying across tasks or situations.
Joint attention – The sharing of attentional focus between two people, either on one another (dyadic, e.g., mutual eye contact) or on a third entity such as an object, event, or idea (triadic, e.g., mutually looking at an object or talking about an idea).
Looking time paradigm – A methodology for studying infant cognition prior to speech by measuring differences in the time infants look at presented stimuli. Longer looking times are richly interpreted by some as indicating mental states or attitudes including 'surprise' and 'preference'.
Number line – A one-dimensional representation of numbers as sequential integers along a continuum (e.g., –3, –2, –1, 0, 1, 2, 3).
Numeracy – Contracted form of 'numerical literacy'; a proficiency with numbers and measures which requires an understanding of the number system, a set of skills for manipulating mathematical information, and ability to reason about quantitative and spatial problems.
Object permanence – A term coined by Jean Piaget to describe the knowledge that objects remain in existence even when they are perceptually obscured (e.g., knowing that a ball hidden from view by a cloth still exists under the cloth).
Ordinality – In development of numeracy, the principle that numbers follow a constant sequential order.
Perspective taking – The ability to take and coordinate different perspectives on the same thing at one time, either multiple perspectives by a single perceiver or different perspectives by multiple perceivers.
Reflex – Species-specific instinctive action elements dependent on stimulation or body position (e.g., sucking an object placed in the mouth).
Representation – Mental manipulation of concrete aspects of persons, objects, or events (e.g., "I like cookies." or "Five is bigger than two.").
Sensorimotor actions – Flexibly controlled actions and perceptions of objects, people, and events (e.g., reaching for a rattle that is seen or heard).
Skills – Organized elements of behavior – including motor actions, thinking, and feeling – that an individual can control in order to meet the demands of a given physical or social context. Skills develop in a complexity hierarchy.
Social cognition – The processing of social information, including perception, encoding, storing, retrieving, and applying social information.
Social referencing – Using another's perception of a situation in order to determine one's own response to it. In infancy, usually referencing a caregiver for information in a novel situation.
Theory of Mind (ToM) – The understanding that others have mental processes – including desires, beliefs, and perceptions – that differ from one's own.

Introduction

In this article we describe early cognitive development from the Neo-Piatetian perspective on the construction of cognitive skills. We first describe the general framework of 'skill theory' including basic tenets and useful metaphors. Then we describe cognitive development through each of three domains – including physical causality, numeracy, and social perspective taking – from infancy through approximately 5 years of age. Finally, we describe sources of variation in cognitive skills both within and across children.

The Shape of Early Cognitive Development

The current state of knowledge of early cognitive development reveals both innate knowledge in the newborn infant and consistent development through eight levels (grouped into three tiers) of cognitive skills through the first 5 years. At first, infants relate to their world by acting on it physically – reacting to stimuli and developing expectations about things and people, then acting with more and more control and forethought. In the middle of

Encyclopedia of Infant and Early Childhood Development (2008), vol. 1, pp. 286-298

their second year, children begin to relate to the world through mental representations, holding information in mind and manipulating it, often accompanied by physical action. Though this consistent sequence of development is underpinned by spurts in brain growth, new levels do not arise simply from maturational processes, but through co-occurrence and coordination of increasingly complex skills. Despite the consistencies across children from which the knowledge of levels is derived, there is both intra- and inter-individual variation in development, showing development to be a web of interconnected skills, rather than a unidirectional ladder.

Cognitive Development as a Web

Developmental ladders and staircases

Development is often conceptualized as a ladder, a metaphor in which development moves along consistent progression toward higher stages. The metaphor of the ladder has three characteristics: (1) development follows a straight line; (2) it progresses along fixed steps in a single sequence; and (3) it is conceptualized as a forward or upward progression, without deviation to the side or movement backwards.

Developmental webs

A better metaphor than the ladder is the web of individual development, in which an individual child moves concurrently along multiple strands in different skill domains. Cognitive development encompasses many different skills developing at different rates along various trajectories toward unique developmental endpoints, and interacting and integrating with one another to produce complex behavior. The web metaphor portrays cognitive development as the complex constructive process that it is, moving along independent strands that can be linked. Indeed the web only begins to capture the complexity of development, which also involves movement up and down along strands and influences between strands. In general, (1) skills vary within a range along a strand, not just at a single level or step; (2) links between domains of development (i.e., social and cognitive development, or neurological and cognitive development) exert bidirectional influence on one another and help to explain the dynamic nature of development; and (3) development involves not only forward progression along a strand but also moving backward along a strand in order to solidify the strand or reshape earlier skills to create a new skill. This article describes several strands of cognitive development, including infants' developing understanding of physical principles, numeracy, and perspective taking. The focus on the strands for these domains grounds understanding of the developmental process, which is always based in children's specific actions in particular situations (Figure 1).

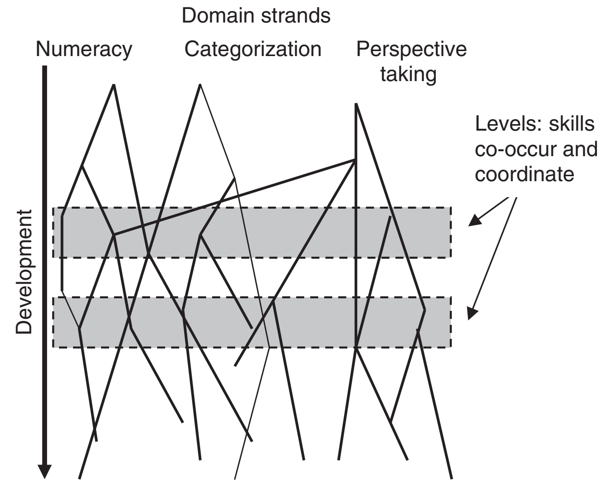


Figure 1 Developmental web showing two levels emerging in three domains. Intra-individual development of domains occurs along independent but intersecting strands, while emergence of new levels corresponds across domains. Adapted from Fischer KW and Bidell TR (1998) Dynamic development of psychological structures in action and thought. In: Damon W and Lerner RM (eds.) *Handbook of Child Psychology. Vol. 1: Theoretical Models of Human Development*, 5th edn., pp. 467–561. New York: Wiley.

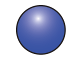
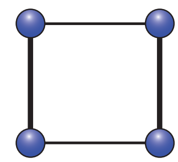
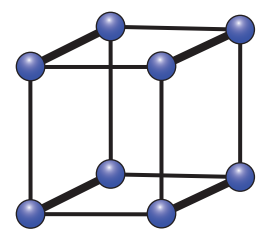
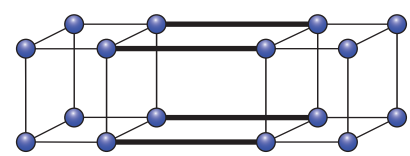
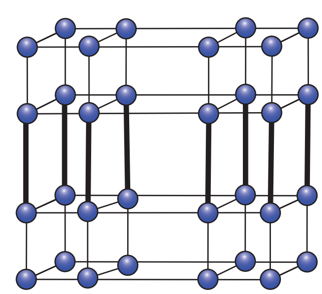
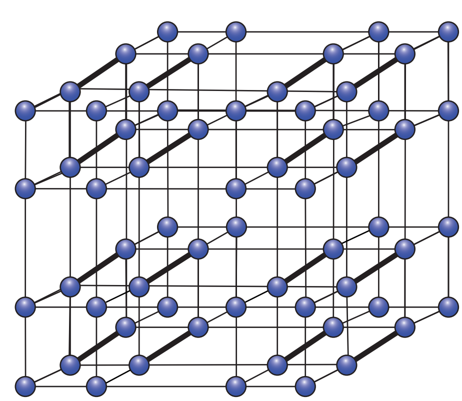
The Process of Developing Cognitive Skills

Skills: The Child in Context

A skill is an ability under one's control within a specific context or task, from visually and motorically exploring a new object to maintaining multiple roles during pretend play. The concept of cognitive skill looks to performances in contexts that elicit them, rather than treating knowledge as an object that is obtained and housed in one's mind. Thus, skills are task specific, but potentially transferable to new contexts through a process of building connections. For example, a 2-year-old child may develop the skill of using a spoon to feed herself cereal from a bowl. She knows what is required in this situation, and is able to control her actions in order to do it. She may be able to transfer this skill to using a spoon to feed herself apple sauce from a bowl, but eating noodles from a bowl or eating beans with a fork are different enough that she needs to work to adapt her skill to this new situation. A skill is not a characteristic of the child herself, nor of the situation, but of the child in context – both social and physical.

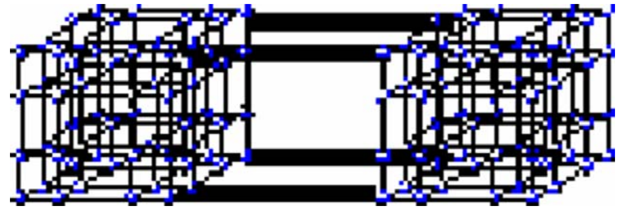
Individual skills developed in later childhood and adulthood vary more in timing and sequence than those developed in early childhood (through age 5 years), where the first eight skill levels show moderate consistency within predictable age ranges. Table 1 shows the age ranges based on research on a number of skill domains, but more research will be needed to specify the amount of variation in skill levels across children and domains.

Table 1 Levels of cognitive development in early childhood

Skill level age of emergence	*Description and example of skills*	*Skill structure*
Single reflex 3–4 weeks	Simple responses to stimuli: infant looks at object moving through visual field; grasps object placed in hand.	
Reflex mapping 7–8 weeks	Using two reflexes together in relation: infant extends arm toward object being looked at when posture allows.	
Reflex system 10–11 weeks	Coordinated system of simple responses: infant opens hand while extending arm to object being looked at when posture allows.	
System of reflex systems, which creates a single sensorimotor action 15–17 weeks	Coordination of two reflex systems: infant extends arm to and grasps object, sometimes adjusting reach as needed and relatively independent of particular postural configuration – which creates a single sensorimotor action, the flexible reach for an object.	
Sensorimotor mapping 7–8 months	Coordination of two sensorimotor actions, such as visually guided reach for an object: infant looks at an object and uses the visual information to grasp it.	
Sensorimotor system 11–13 months	Complex relations of sensorimotor action relations into a flexible system, such as visual/manual exploration: Infant uses visual information to manipulate an object and moves it to see different aspects of it. Infant also relates sound and vocalization, using single word to label object.	
System of sensorimotor systems/single representation 20–24 months	Integration of sensorimotor action systems into a concrete representation: child manipulates an object to make it carry out actions in pretend play, making a doll walk or talk, talking into a toy telephone. Child also describes attributes or actions of objects and people.	

Continued

Table 1 Continued

Skill level Age of emergence	*Description and example of skills*	*Skill structure*
Representaitonal mapping 3.5–4.5 years	Coordination of two representations: child uses two objects in pretend play, relating their actions to one another, e.g., pretending that a mother doll is taking care of a child doll. Child also uses language to coordinate attributes and actions appropriate to ascribed roles, such as mother and child.	

Reference: Fischer KW and Hogan AE (1989) The big picture for infant development: Levels and variations. In Lockman J and Hazen N (eds.) *Action in Social Context: Perspectives on Early Development* pp. 275–305. New York: Plenum.

The Process of Development: Getting from One Level to Another

Convergent findings in infant research demonstrate several periods of rapid change in cognition, producing discontinuities – or shifts in level – in cognitive skills. These periods of rapid change are 2–4 months, 7–8 months, 12–13 months, 18–21 months, and 4 years. Evidence indicates that changes in growth patterns of brain activity and anatomy underpin these cognitive changes. While this association of cognition and neurology shows maturational underpinnings for shifts in skill levels, it does not alone explain development from one level to the next; available evidence does not indicate one direction of causality between cognitive skills and brain growth.

Skill levels form a hierarchy that develops in consistent sequences within domains through the process of co-occurrence and coordination. Levels are grouped into tiers, three of which fit within early childhood: the tiers of reflexes, sensorimotor actions, and representations. At each tier, children differentiate and combine the skills under their control so as to move through a series of levels that eventually create the elements of the next tier. Reflexes, which are simple elements of voluntary action by the infant that depend on inborn patterns of posture and action, differentiate and combine to produce sensorimotor actions. Sensorimotor actions, which are flexible and coordinated actions on objects, are in turn differentiated and combined to develop a third type of cognitive unit – representations. Representations are mental manipulations of concrete aspects of persons, objects, and events. This process of skill elaboration goes on through development at later years into the 20s until abstract systems are combined to create principles in adults. However, the scope of this article covers cognitive development only in early childhood – to the level of representational mappings.

Children develop more complex cognitive skills through the processes of co-occurrence and coordination. The co-occurrence of two skills, both elicited by a given task, induces the child to notice them in contrast to one another, differentiating and coordinating them by using them together in subsequent tasks. Through these processes, increasingly complex skills are built in a sequence for each domain, like cognitive building blocks. Table 1 provides a list of the skill levels, the typical ages at which they emerge, a description and example of each level considered in this article, and a pictoral representation of the skill level to facilitate understanding of the process of building complex cognitive skills through co-occurrence and coordination of simpler skills.

Like the type of skill, developmental level is not a characteristic of the child, but of the child in context. The level of a skill, as well as its type, depends on the task itself – including the demands of the task and the child's familiarity with it. Other important sources of variation in skill level come from within the child (such as internal state) and from the supports provided to the child within the environment. Because the type and level of skill vary within their context, the structure of skill development is different from that proposed by Jean Piaget, who contended that children develop through generalized stages of skills; that is, a child at a particular stage would exhibit behaviors consistent with that stage in all tasks. Instead, children operate at different skill levels for different tasks, depending on the sources of variation described above. This is why *décalage* – a term used by Piaget to describe the variation in cognitive abilities across tasks and situations in a single child – is the rule rather than the exception in cognitive development. Even highly educated adults will use very basic, low-level skills when they encounter an unfamiliar task. Variation across children shows that the progression from one level to the next is not as simple as expectable maturation (i.e., it is not merely a result of brain development). Instead, progressing from one level to another is a result of a combination of factors, including children's maturation and their experiences performing skills.

Typical Development of Early Cognitive Skills

This section describes the typical development of early cognitive skills, from newborn through age 5 years, from the earliest levels measured through representational mappings. The focus is on the development of skills for physical causality, numeracy, and perspective taking. (To date, much less is known about the 'reflex levels' – when children are typically 4 weeks to 4 months – than the other levels. We present only what is known currently, thus descriptions of cognitive development through these levels are limited.)

Physical Causality

From basic reactions to physical objects, to intentional actions on and with objects, followed by representations of object functions and relationships to one another, young children build their knowledge of physical causality. The ability to categorize objects by their functions (or effects) contributes to children's use of objects in problem solving, as well as understanding of causality.

Newborn

Within their first few days and weeks of life, infants can demonstrate that they already know a number of things about the physical world. Newborn infants will follow a moving object with their eyes, and infants demonstrate a perception of the world as three-dimensional – for example, by showing an expectation that objects remain the same size across situations. Throughout the early months, infants' actions are seriously limited by the particular postures or positions of their body. For example, they can look at an object on the side that their head is turned, but have great difficulty following the movements of that object past the midline, where they would have to shift their body to position their head for looking at it.

Reflex levels

Single reflexes. By 3–4 weeks of age infants have a number of reflexes under their control for responding to stimuli. Some of those most widely studied are looking toward or away from an object presented in their visual field, grasping an object placed in their hand, and kicking their legs, all of which depend on their being in a specific bodily position supporting the reflex.

Reflex mappings. Beginning between 7 and 8 weeks, infants can coordinate two reflexes into a reflex mapping. For example, they can extend their arm toward an object held in their view, provided that their posture places the arm in a position to reach in that direction.

Reflex systems. Around 10–11 weeks, infants can coordinate two reflex mappings to create a reflex system. For example, they will open their hand while extending their arm toward an object held within view, so long as their body is in a position that supports this movement. Further, 3-month-old infants seem to know that they can cause events, though because their actions are primarily reactions they do not know how they carry out a means to cause the event. By tying one end of a ribbon to a mobile, and the other to an infants' foot, infants will learn that when they kick that foot, the mobile moves, and will even remember to kick that foot if shown the same mobile a week later. But if the ribbon is loose, they do not figure out how to vary their action to take account of the loose ribbon. Also, when the ribbon is removed, the infants still kick their foot, as if expecting the mobile to move. They seem to have learned 'when I act, interesting things happen'.

Sensorimotor levels

Sensorimotor actions. At 15–17 weeks, infants can combine reflex systems into single sensorimotor actions. At this point, they begin to guide and shape their reaching, extending an arm toward an object to grasp it in different positions or to adjust to it as they open their hand, and sometimes adjusting their hand if the object changes position. Through this level, children come to use a variety of different actions on objects, including systematically dropping them from wherever they sit; importantly, they do not yet look to see where objects land when dropped.

Sensorimotor mappings. At 7–8 months, infants combine sensorimotor actions into simple sensorimotor mappings. For example, an infant can now reach and grasp an object (a sensorimotor action) in order to pull it closer and look at it. Infants at this level demonstrate an ability to distinguish between objects as either animate or inanimate. By 10 months, infants show awareness of basic 'billiard ball' causality, the idea that action is caused by something. Infants who have habituated to a toy car moving after being bumped by another moving toy will look longer when the conditions of causality are not met – for example, when the car begins to move before the other toy has bumped into it to cause the movement. Infants also demonstrate expectations consistent with an understanding of forces besides personal agents, such as gravity: They will drop an object to the floor and look accurately to see where it landed (**Figure 2**).

Sensorimotor systems. Around their first birthday, 11–13 months of age, infants begin to combine sensorimotor mappings into systems of sensorimotor actions. An infant at this level can actively explore objects by moving them around to see different sides. As a result of this new coordination, infants begin to understand more about objects' relations to and effects on one another, and can use this knowledge to achieve their own goals. For example, a 12-month-old child can pull a cloth to obtain a toy that is sitting on it, and will not pull the cloth when the toy is not resting on it (indicating an understanding of the relationship of support), whereas an infant at the previous level will pull the cloth hoping to obtain the object, even if the object he wants is held above it.

Controversy in interpretation:
Rich vs. conservative explanations of infant behavior

Rich interpretation of infants' behavior is the explanation of infant behavior in terms of adult-like mental activity. Some of the methods we describe in this article– such as habituation and looking time – lead to results which could be interpreted in either a rich or conservative way. An ongoing controversy affecting both the theory and methods in the field of cognitive development asks, is a rich interpretation of infant behavior or a conservative one more accurate and more useful for understanding the results found in studies of infant cognition?

Marshall Haith put forth a heuristically challenging argument against rich interpretation, asserting that such explanations of infant behavior provoke a number of problems in the field of infant cognition. These problems include claims that very young infants have knowledge they could not yet have reasonably acquired, use of concept, minimally supported claims that certain knowledge is innate, and undermining the study of development of cognitive skills over time.

On the other hand, many developmental theorists who are proponents of the 'competent infant' idea believe that conservative interpretations of infant behavior too often underestimate infants' abilities, failing to see the thoughtfulness and intentionality behind the behaviors of preverbal children.

From the perspective of Skill Theory, infant behaviors such as longer looking times or preferential head-turning likely indicate the beginning building blocks of cognitive skills which will be elaborated and generalized into their adult forms later in development.

Figure 2 Controversy in interpretation: rich versus conservative explanations of infant behavior.

Infants begin to recognize rudimentary object categories based on appearances. For example, they will show surprise when a duck emerges from an occluder instead of the toy car that went behind it. Prior to this, infants rely on trajectory as the primary way to identify an object. Infants at this level will group toys by object type (e.g., plastic farm animals vs. toy cars), whereas at 9 months they show less interest in or understanding of object categories.

Representations

Single representations. Around 20–24 months, young children coordinate systems of actions to produce concrete representations. It is at this point that they begin to engage in symbolic play with objects (e.g., representing toys as having particular uses or roles), rather than functional play (simple actions on and with objects). Related to their growing understanding of causality, children's skills for manipulating objects have also become far more complex. A child will use a tool to get a toy that is out of reach, showing emerging planning and problem-solving skills.

At this level children begin to categorize objects spontaneously, carefully organizing objects by category (e.g., horses vs. pencils), stacking them or lining them up, a skill that displays their capacity to represent concrete properties of objects. Combining their skills in categorization and causality, 2-year-olds will begin to categorize things by function rather than form. Alison Gopnik and colleagues showed children a series of novel objects that looked similar to one another. Then children were shown that two of the objects shared a function. The experimenter told the children that one of the objects was a blicket, and asked which of the other objects was also a blicket. Two-year-old children chose the object that had performed the same function as the first blicket rather than one more similar in appearance.

Understanding why an object does what it does is another matter, however. Toddlers often still act as though they believe that they (or another person-agent) must act in order to make interesting events happen. When interacting with a wind-up toy, they will physically manipulate the object to perform its action rather than using the mechanism. Even when the physical demands of the task are far easier than locating and manipulating a winding mechanism, toddlers will still use more of their own force than necessary to cause an event. Besides winding up a toy unnecessarily, they will push a toy car down a ramp rather than releasing it to roll.

Representational mappings. At this level, emerging around 3.5–4.5 years of age, children begin to relate concrete representations to one another. Categorization skills are more sophisticated, and children will categorize objects by their underlying natures, and use categories to appropriately ascribe characteristics. With this more sophisticated understanding of categories, pretend play becomes much more common and complex; for example, in play children will ascribe roles to the dolls and maintain them throughout the dolls' interactions with other objects or people, using the doll as an actor or cause.

Children at this level display their knowledge of causality through their use of language, beginning to give reasonable causal explanations, as well as to make simple if–then causal predictions about simple mechanisms and interactions in the physical world, based in representations of how events occur in relation to each other. Children's explanations of the causes of events often reveal, however, the same kind of teleologic reasoning that their earlier actions displayed; young children explain events as happening 'so that' rather than 'because of'. For example, Piaget discovered that when children explain events in nature, they indicate that rain is occurring 'so that we will have water', the sun goes down at night 'so that we can sleep'. At this level, causes are still thought of as forces coming from active agents for a purpose under the agent's will, such as that the wind makes the clouds move.

Throughout early development, children's understanding of the causes that can produce effects grows from a sense of self as agent, to others as agents, and then to interactions among agents and objects. Around the age of 5 years, children understand that forces other than people cause events, but these forces are still personified. Indeed, listening to adults' explanations of events may reveal that though they may know better, they do not lose the tendency to explain events in terms of personal forces and teleological purposes.

Numeracy

Research with infants and others has revealed two number systems that people develop to mentally track numbers – an exact system used for small numbers and an approximate system used for estimating larger magnitudes. Within their first year of life, infants' abilities to differentiate varying magnitudes improve to detect smaller ratios, while the specific numbers an infant can track using the precise system increase during the course of early childhood, from just 1 and 2, to 3, then 4, then to having a sense of the number line. After children understand the number line, and sets or groups of objects represented by a single number, they begin combining components of their knowledge of number in increasingly complex ways.

Newborn

Based on habituation with looking time, infants have been shown to recognize the difference between one, two, and three objects under a variety of different testing conditions. This has been found as young as 2 and 3 days after birth. Newborn infants' attraction to visual stimuli with high contrast, and to the edges or boundaries of objects within their view, gives an indication of infants' attention to identifying singular objects, or ones. Even in their first few days, infants appear to notice the constancy (and change) of object number, though this is limited to smaller numbers.

Reflex levels

During the reflex levels, infants are learning to parse visual stimuli in appropriate places and identify objects as unitary, counting as one thing. Along with attention to high-contrast edges, infants rely on motion to determine the boundaries of an object. For most objects, what moves together stays together as one object; and infants have been shown to expect this basic principle. A lamp and coffee table both made of the same color wood may appear to be one oddly shaped object because there are no stark contrasts; however, when someone lifts the lamp from the table, anyone – including the infant – can see that they are two distinct objects. It is no surprise, then, that from birth infants will follow a moving object with their eyes. Research has also shown that infants are more sensitive to the trajectories of an object than to its surface characteristics in determining the identity of an object. An infant will show more surprise and curiosity (looking longer or looking again) toward an object emerging from an occluder when the object has changed speed or direction than when it has changed shape and color. Research with congenitally blind children and adults who have gained sight confirm the necessity of motion for identifying singular objects; a newly sighted individual tends to parse visual stimuli in inaccurate places until they see an object move.

Sensorimotor levels

Sensorimotor actions. Can infants add and subtract? At this level, studies by Karen Wynn with a series of physically impossible events show that infants as young as 4.5 months of age can add $1 + 1$. Infants saw one Mickey doll on a puppet stage, then saw the Mickey doll occluded. Next they saw a hand come from the side of the stage to place another Mickey doll behind the occluding screen; when the screen came down, they saw either one or two Mickey dolls. They had not seen the dolls together before, so that the scene of two dolls on the stage was technically novel, not seen before. However, they looked longer when there was only one Mickey on the stage, showing that they expected to see two, because one had been added to the other; they were surprised at seeing only one. The same experiment works for subtraction; when infants are presented with two Mickey dolls, and one Mickey is taken away (from behind an occluder), infants expect to see only one and show surprise when there are still two. Further, the infants showed surprise with three objects as well, leading to the conclusion that 5-month-old babies do indeed know that $1 + 1 = 2$, not 1, and not 3.

Sensorimotor mappings. Using habituation of sucking rhythm (rather than looking time), experimenters have shown that young infants' sense of numeracy extends to sounds as well, for tones and for syllables; after being habituated to words with three syllables (or to three tones), infants respond with more interest (more vigorous sucking) when they hear words with two syllables (or two tones). Testing infants' numeracy across sensory modalities, Elizabeth Spelke and colleagues used looking time to show that infants between 6 and 8 months of age prefer to look at slides of two objects while hearing two drum beats, and three objects while hearing three drum beats. It appears that infants can identify the number of sounds they hear and compare it to the number of objects they see, leading to the conclusion that infants' perception of small numbers is both general and cross-modal.

In addition to advances in the system for precise number, infants at this level are learning to discriminate smaller ratios of magnitude in both the visual and auditory modality. Using looking time as an indicator of novelty recognition, Spelke and colleagues have shown that 6-month-old infants can estimate magnitude differences of 2.0 (e.g., 8 vs. 16 objects, 5 vs. 10 objects), while 9-month-olds can detect ratios of 1.5 (e.g., 8 vs. 12 objects) as well as 2.0. Using a method in which infants' head turning toward sounds is used to indicate recognition of novelty, Spelke and colleagues have more recently shown that this same timing of magnitude recognition holds in the auditory modality as well.

The statistically sensitive infant. Another way of detecting where one thing ends and another begins is by determining the likelihood that a particular thing will follow another. In the phrase 'happy day', how does a child learn that the syllables 'hap' and 'py' are one word and 'day' another, rather than 'hap pyday'? A series of studies has shown that infants as young as 8 months old are incredibly sensitive to the statistical likelihood of word syllables being heard together, thus defining the boundaries of words within a continuous stream of sound. Other studies have shown that the same learning mechanism works with visual as well as auditory stimuli – that infants expect to see a certain sequence of pictures when they have seen the same sequence a number of times, and that they look longer when the sequence is violated.

Sensorimotor systems. Around 12 months of age, infants begin to distinguish small numbers more consistently. Conservation of number in the early months of life rarely goes beyond the number three; in only a few tasks in a few different laboratories have infants been seen to correctly conserve (or add) 4, as opposed to three, and no infants under 12 months have been observed to distinguish 4 from 5 or 6. However, getting to three is important because it shows that babies are not just distinguishing 'one' vs. 'more than one'. Around 15 months of age, after learning basic addition and subtraction of small numbers, infants combine these skills to develop a sense of basic ordinality of quantity; that is, that three is larger than two. When offered a choice, they will select the larger group of toys.

Representational levels

Single representations. At this level, young children are beginning to use verbal language more fluidly; they have a representation of the concept of more and can respond to verbal instructions to choose a line with more things in it. Piaget made the observation that for large numbers, young children will choose the longer line of objects when asked to choose which line has more. However, subsequent studies have shown that for very small numbers children around age 2 years will choose the correct line of objects (i.e., marbles) when asked which line has more, even when the one with less is made to look longer.

Representational mappings. Coordinating the concept of the ordinality of the number line with the concept that a group of objects can be represented by a single number, children between 3 and 4 years old learn the rule of cardinality; that is, for counting the objects in a set, the last number counted is the number of objects in the set. However, overgeneralization of this rule can lead to miscounting until children coordinate it with more sophisticated understandings of object identity. For example, when asked to count how many pencils are lying on the table, if one pencil is broken in two, a child of 3 or 4 will count it as two pencils, concluding that there is one more pencil in the set than there really is. Children at this level understand that you count each object in order to derive the number in the set, but have not yet coordinated what they know about object identity to take into account the unity of the broken object.

There is a spurt in the development of numeracy between ages 4 and 5 years, as many children construct the number line. That is, with the knowledge that numbers are ordinal, children at this level extend their representations of individual numbers – 1, 2, 3, and 4 – into a number line, for numbers in general to 5 and beyond.

Perspective Taking

Perspective taking is one of the foundational skills for social interaction, including the recent line of research on 'theory of mind'. Understanding of self and other is reconstructed at every level of cognitive development, and perspective taking begins at the reflex levels with actions in response to others, and in response to self. This is followed by the coordination of perceptions of and actions toward self and other at the sensorimotor levels. Then at the representational levels, children begin to coordinate increasingly complex combinations of both similarities and differences between self and other, including the very challenging matter of differences in perspectives, thoughts, and beliefs. Though Piaget described children's ability to take and coordinate multiple perspectives on a single object or concept as developing around the age of 8 or 9 years, extensive research shows how precursory skills for perspective taking develop in the first 5 years.

Newborn

From the time they are 1 h old, infants can respond to others by imitating a few simple actions they see on another's face; there is the most evidence for newborns' ability to imitate sticking out the tongue.

Reflex levels

Single reflexes. At this level, infants respond to social stimuli, such as turning toward a familiar voice or staring at a likeness of a face, so long as their bodily position supports this reflex action.

Reflex mappings. Beginning between 7 and 8 weeks of age, infants can bring together two reflexes into a coordinated reflex mapping. For example, while looking into their mother's face, they will look at her eyes in response to her voice. Infants also show some sensitivity to contingencies during interaction and begin to show upset when interactions are noncontingent, that is, when mother's responses to changes in her infant's looks and vocalizations are delayed or nonexistent.

Reflex systems. At 2–3 months of age, infants can coordinate reflex mappings into a smooth system of social responses, smiling and cooing in response to facial and vocal cues from adults, so long as their bodily position facilitates these actions. They begin to coordinate their own facial expressions, gestures, and vocal productions with those of others for a contingent turn-taking game with rhythms similar to conversation.

Sensorimotor levels

Philosophers and scientists have debated whether self-knowledge is derived from knowledge of other, or the reverse. Scientists Sandra Pipp, Kurt Fischer, and Sybillyn Jennings examined the development of knowledge of self and other in children aged from 6 months to 3 years by posing a series of sequentially ordered tasks requiring children to demonstrate knowledge of self and mother in two different domains: agency (action on self and other), and features (recognition of attributes of self and other). Their findings show that self- and other-knowledge develop concurrently, and the primacy of each depends on the particular domain (agency or feature). This is another example of intersecting strands of the developmental web.

Sensorimotor actions. At this level, infants begin to act toward others – typically caregivers – in order to elicit desired responses. They no longer merely respond, but regularly initiate interactions and manipulate others' actions. Relatedly, they begin to recognize and respond to distinct internal states in others, differentiating (as tested by looking time) facial expressions consistent with the emotions of anger, fear, and surprise in female adults. At 6 months of age, infants can interpret the goals of human actions and show surprise (longer looking time) when the human hand reaches for the 'wrong' thing (a different goal object). The effects are not seen when the task is done with a nonhuman, mechanical hand. Now that infants guide their own actions to facilitate their own rudimentary goals, they interpret others as capable of having goals or interests that likewise guide action.

Sensorimotor mappings. At this level, infants begin to coordinate a few social behaviors in order to engage, re-engage, and direct the attention of others. Around 9 months of age, infants begin to consistently engage in joint attention with another person, coordinating their actions to engage in and direct others' attention. As early as 7 months of age, infants will attempt to re-engage partners in dyadic joint attention, coordinating sensorimotor actions (such as gaze following, and some early pointing) to engage in dyadic joint attention. By the age of 10 months, infants use these behaviors consistently in social interaction, as when they engage a partner during exploration of a toy.

In the study by Pipp and colleagues, infants successfully performed agency and feature tasks directed at oneself and mother. In the agency tasks, they followed the experimenter's request to feed themselves or their mother a Cheerio. Agency toward oneself developed slightly earlier than agency toward mother. In contrast, the order was reversed for features: Infants at this level successfully identified mothers' features in the mirror, but not their own.

Identification of features in others at 10 months of age includes attribution of social qualities and rudimentary psychological attributes to individuals. In studies by Karen Wynn and colleagues, infants saw one object (a geometric shape with eyes) apparently trying to climb a hill, and another object either apparently helping or hindering the first in reaching its goal. In a subsequent scene, the climbing object moved to be near either the helper or the hinderer. Infants showed surprise (longer looking time) when the climber moved next to the hinderer rather than the helper. This surprise indicates that infants attribute some quality to the helper and hinderer, and expect a certain reaction or disposition toward these two individuals from the climber. Given the opportunity to play with one of these objects after viewing the climbing scene, infants chose the helper object rather than the hinderer.

Sensorimotor systems. Around 12 months of age, infants' social cognition becomes noticeably more complex. They begin coordinating their responses with those of others, looking to others to guide their own actions – using social referencing in ambiguous situations. There is a rapid increase in the use of pointing to direct others' attention at this level, and more consistent following of adults' pointing. Infants will also imitate adults' actions on objects, even when there is a delay between when they see the action and when they get an opportunity to imitate it. At this level infants seem to be learning that they are like others, which informs their responses to their environment. They are aligning their attitudes and actions to those of others.

In the Pipp study of self and other, infants around 12 or 13 months of age passed a simple visual recognition task by identifying in a mirror a sticker placed on theirs or their mothers' hands. On average, infants passed this visual identification task for mother at earlier ages than for self and similarly identified rouge on their mother's face in a mirror around 15 months, 3 months earlier than they identified rouge on their own face.

At 14 months of age (but not 12 months), infants coordinate more complex social information to make distinct attributions of psychological dispositions. Studies by Wynn and colleagues used an elaboration of the climber task previously described in which there were two climbers; one climber was helped and one was hindered by the same third object. Children showed the expectation that the climber who was helped would move toward the third object while the climber who was hindered would move away. That is, they did not perceive the third object as simply a helper or hinderer, but differentiated how each climber would react to it based on their experiences.

Representations

Single representations. As children move into the representational levels, they hold aspects of self and other in mind beyond their immediate experience. Around 18 months of age, children understand that other people's desires or preferences can differ from their own. Alison Gopnik and colleagues have conducted a series of experiments in which an experimenter demonstrates by facial expression and voice that she prefers broccoli to goldfish crackers, then places her hand right between the two bowls of food and asks the infant to give her more. Whereas a 14-month-old will give the experimenter more crackers (the food that the child prefers), an 18 month old will give the experimenter more broccoli. At 18 months of age children understand that the experimenter's desires are discrepant from their own. Though children as young as 18 months of age have learned that desires can differ, they do not yet understand that perspectives can differ (the apparent discrepancy here is discussed below). The inability to coordinate multiple perspectives results in humorous behavior by toddlers, such as a child covering his own eyes as he walks past his parents with a stolen cookie, believing that if he could not see them, then they could not see him.

Showing insight into others as agents with intentions, 18-month-olds will re-enact the intended, rather than observed, act of a person. Children can infer the adult's intention by watching the failed attempts, and will later do the intended action, rather than the one they saw actually done. The fact that they do not show this same intention reading when they observe a machine 'fail' at a task reveals that they are attributing internal goals and intentions to human beings.

Self and other representations show differences similar to those earlier in infancy. For the feature tasks in the Pipp study, infants recognized rouge on their own nose at around 18 months, after they had noticed it on their mother's nose, thus developing skills for other before self. For the corresponding agency tasks, infants' pretended to feed themselves and their mothers or to drink. They succeeded at this task earlier for self than for mother, thus developing skills for other before self.

Between 18 and 36 months of age, infants coordinate more and more complex representations of self and other as agent and self and other features. In the Pipp agency tasks, infants acted on another person within a prescribed interaction, interacted with another within a prescribed role, and eventually represented two distinct social roles (mother and baby) in pretend play tasks. In the features tasks, children identified increasingly abstract aspects of self and other by correctly responding to a series of questions involving self and other in spatial location ("Where is (Mommy/Child's name)?"), as actors ("Who did that?"), as owners ("Whose is that?"), in familial relationships ("Who do you belong to?"), and in gender categories ("Are you a boy/girl?"). There was a small advantage for self-knowledge in the agency tasks and for other knowledge in the features tasks. At 3 years of age, children have built complex representations of others' characteristics, including concrete visual perspectives, so that they can hide a toy so that they can see it but another person cannot.

Representational mappings. At 3 years of age, children have already built complex representations of self and other, representing basic roles and identifying features. Around 3.5–4.5 years, they begin to coordinate these representations in more and more complex ways, coming to understand many differences between self and other, as well as differences between current and past self – in visual perspectives, thoughts, and beliefs. Children use language to explicitly contrast representations. Conversations between young children and their parents recorded in the CHILDES database reveal children between 3 and 4 years of age pondering contrasts between characteristics of people such as what they like and do not like.

Between 3.5 and 4 years of age children begin to represent different, contradictory perspectives of their own and others. Extensive research on 'theory of mind' uses false-belief tasks, which require coordination of representations of beliefs and perceptions in self and other – for example, differentiating between one's own current and past beliefs, or contrasting one's current knowledge with another's ignorance of a fact or circumstance. In order to pass these tests, it is necessary to understand that people have thoughts and beliefs about things, that people can

Encyclopedia of Infant and Early Childhood Development (2008), vol. 1, pp. 286-298

have different thoughts and beliefs from one another, that those thoughts and beliefs can change, and that those thoughts and beliefs can be wrong, as well as right.

By the age of 5 years (typically), children understand that other people have minds in a way that has much in common with adults' understanding. They know that a number of different internal states exist and have specific characteristics: thoughts, beliefs, emotions, desires, and perceptions. But they still have difficulty coordinating all of these together until later skill levels at older ages.

Variation within Children

For any given cognitive skill, the child has a developmental range of performance with a lower bound called the functional level – the child's best performance with low support – and an upper bound called the optimal level – the child's best performance with high support. The concept of developmental range is related to, but more specific than, 'Vygotsky's zone of proximal development', which includes 'scaffolding', in which a more skilled partner such as the parent actually performs part of the task jointly with the child. Developmental range encompasses what children can do on their own with and without support, or in optimal or functional (ordinary) conditions. Thus, both individual characteristics (interest, emotion) and environmental contexts shape within-individual variation in cognitive performance.

Tasks

Different tasks often produce variation in performance, even if they appear to elicit similar cognitive processes. An example of the effect of task context on children's performance in numeracy is found in studies of children's ordinality concepts. Children aged between 2 and 4 years will choose the line with more M&Ms when asked which they would rather eat, but when asked about two rows of marbles, "Which one has more?" the 3- and 4-year-olds choose the longer line with fewer marbles. When the choice in the task is based on the child's own motivation (with the M&Ms), children answer correctly, but when they must interpret the experimenter's meaning, they often answer incorrectly. More generally, different tasks elicit different performances in children, even when the tasks seem to have similar cognitive demands. Counting M&Ms is not the same as counting marbles, and counting people or buildings are different in other ways. Children perform differently in different tasks, even when adults see the tasks as equivalent.

Environmental Support

There are countless ways in which the child's environment can facilitate or hinder performance of cognitive skills. Support can take many forms, from physical support of an infant to facilitate a reach, to priming with information to facilitate success on a task. The most consistent example of varying performance in early childhood is the difference between what infants can do when they are or are not in an optimal physical position, usually supported. Eye–hand coordination illustrates this difference dramatically: A 2-month-old infant seeing an object may be able to reach out and grasp it successfully when he or she is positioned at just the right angle to both see the object and easily reach it. In other postures, however, this behavior disappears immediately; and the infant cannot perform it consistently in many different postures until several months later.

Emotions and Internal States

In order to perform at an optimal level, a child's internal state must facilitate performance. State limitations are especially severe for young infants, who must be alert but not overly aroused in order to produce organized voluntary reflex actions. Internal states continue to play a role in cognitive performance throughout life, but as children gain more self-regulatory skills, they are better able to manage internal states in order to attend to cognitive tasks.

Emotional states continue to shape performance and development even when children are alert and focused on a task. Emotions evoke particular patterns of activity and bias behavior in certain directions. In representing self and other, for example, most children from a young age naturally represent the self as good and nice, and they reserve representations of bad and mean for other people. In examining children's stories about positive and negative social interactions, Kurt Fischer, Catherine Ayoub, and their colleagues found this bias of 'me nice but you mean' in most young children. Of course, children sometimes have great fun pretending to be the bad guy as well, but in most situations children growing up in stable, supportive environments show biases toward representing self as positive.

Variation Across Children: Webs and Pathways

Given the consistent sequence and typical timing of development of early skills, what explains the variations that occur across children? Variation in development involves both the speed and timing of change and distinct pathways arising from divergent experiences, abilities, and cultures.

Timing

Children typically develop at different rates across domains, while keeping the same general order of development. They progress through the same levels of skill development, but move more quickly than their peers in some domains and less quickly in others. These variations stem from both different experiences in particular domains and diversity in ability and motivation across children. Some cognitive tests – the Bayley Mental Index, for example – test cognitive skills as if they are a singular set. In such tests, items are ordered in a single line and children are expected to pass nearly all items subsequent to their own highest item. In contrast to this, others – such as the Uzgiris-Hunt test – are composed to examine children's cognitive skills in particular domains of knowledge. In such tests, items are grouped by domain, and children may have a different score, and different ranking amongst their peers, on each scale. Either of these tests can identify differences in timing of skill development, but use of a unitary intelligence test leads to interpretation of children as generally lagging behind or speeding ahead of their peers, whereas use of a domains test leads to identification of differences across distinct contexts and tasks.

Adaptations and Perturbations

Within a traditional framework of development as a ladder going in a single direction, any variation or discrepancy is interpreted as either delay or pathology. However, within a framework viewing development as a web of interconnected skills that arise in specific contexts, variations in development are adaptive responses to differing circumstances. For example, children's representations of self and others as nice and mean in social interactions develop along distinct webs for abused children compared to nonabused and for shy compared to outgoing children.

In stories about positive and negative interactions children who have been maltreated develop along distinct but equally complex pathways: Most commonly, they build complex stories about mean interactions, and simpler, less developmentally mature stories about nice interactions. If assessments require them to focus on positive interactions, their development appears delayed or retarded, but assessments that include their natural focus on negative interactions demonstrate that they function at normal developmental levels in that domain.

Emotional differences in temperament shape children's pathways in another way: Shy (temperamentally inhibited) children show typical development of the representation of self and other as positive (nice, good), but even in pretend play, they often avoid and resist representations of negative interactions, especially when they themselves are represented negatively (as mean or bad). Uninhibited, outgoing children, in contrast, often relish pretending to be mean and thus develop richer, more complex negative representations of self and other.

Cultural Variation

People organize their mental tools and the structure of their cognition through the symbols of their cultures, as Lev Vygotsky emphasized. Cultures shape people in the developmental pathways for building the tools through participation in everyday social interactions and cultural rituals, thus producing important differences in meaning systems. In an example of cultural differences in dominant symbols, people in China and the US give different prominence and meaning to concepts and tools related to shame. Chinese culture makes shame prominent from an early age and uses it to direct behavior constructively toward prescribed cultural norms. It includes tools for coping with shame and related transgressions and teaches these tools and concepts from an early age through storytelling routines by parents and other adults. European-American culture uses shame differently, minimizing its explicit use with young children and providing few culturally supported tools for dealing with it. As a result, Chinese and European-American children differ greatly in their understanding of shame, Chinese children showing basic use of the concept by 2 years of age, whereas European-American children do not use it until around age 7 years. In China, shame is a cultural tool that shapes individual relations to social groups. In the US it is something that is unhealthy and should be avoided. People from each culture have difficulty understanding what shame means in the other.

Cultures shape important differences in many other domains as well, reflecting differential emphases in language and cultural practices. For physical properties of objects, Korean children develop an early focus on actions, while English-speaking children focus more on objects. Korean mothers use more verbs in their speech to children, talking about actions; whereas English-speaking mothers use more nouns, doing more object labeling. Korean children go on to solve certain action puzzles earlier than English-speaking children, such as obtaining an out-of-reach object using a rake-like tool. English-speaking children, in contrast, categorize objects more frequently at earlier ages than the Korean children. In general, cultures create variation in timing and developmental pathways of early skills in particular domains.

Summary

Early cognition proceeds from reflex (reaction) to intentional action and then to representation, building increasing complexity through a series of levels of development. Children build distinct, individual skills, and developmental pathways vary across domains within children, with each child forming a developmental web with many strands. At the same time cognitive skills develop in a predictable, standard hierarchical sequence in each strand, and the timing of major advances seems to correspond to spurts in brain growth. Each individual child varies her or his level of functioning dramatically as a function of support, context, and interest. Different children vary in the specific strands that they build and their connections among strands. These variations result from differences in experience – including both benign cultural experiences and extreme experiences such as abuse – as well as in interests and temperament. In developing skills and understanding, children adapt to the specific environments where they live and to their individual abilities, emotions, and other characteristics.

See also: Amnesia, Infantile; Bayley Scales of Infant Development; Categorization Skills and Concepts; Cognitive Developmental Theories; Developmental Disabilities: Cognitive; Mathematical Reasoning; Milestones: Cognitive; Object Concept; Piaget's Cognitive-Developmental Theory; Taste and Smell; Theory of Mind; Reasoning in Early Development; Vygotsky's Sociocultural Theory.

Suggested Readings

Case R (1992) *The Mind's Staircase: Exploring the Causal Underpinnings of Children's Thought and Knowledge.* Hillsdale, NJ: Erlbaum.
Fischer KW, Ayoub CC, Noam GG, Singh I, Maraganore A, and Raya P (1997) Psychopathology as adaptive development along distinctive pathways. *Development and Psychopathology* 9: 749–779.
Fischer KW and Bidell TR (1998) Dynamic development of psychological structures in action and thought. In: Damon W and Lerner RM (eds.) *Handbook of Child Psychology. Vol. 1: Theoretical Models of Human Development,* 5th edn., pp. 467–561. New York: Wiley.
Fischer KW and Bidell TR (2006) Dynamic development of action, thought, and emotion. In: Damon W and Lerner RM (eds.) *Theoretical Models of Human Development. Handbook of Child Psychology,* 6th edn., vol. 1, pp. 313–399. New York: Wiley.
Fischer KW and Hogan AE (1989) The big picture for infant development: Levels and variations. In: Lockman J and Hazen N (eds.) *Action in Social Context: Perspectives on Early Development*, pp. 275–305. New York: Plenum.
Gardner H (1983) *Frames of Mind: The Theory of Multiple Intelligences.* New York: Basic Books.
Gopnik A, Meltzoff A, and Kuhn PK (1999) *The Scientist in the Crib: What Early Learning Tells Us about the Mind.* New York: William Morrow & Company.
Gruber HE and Vonèche JJ (eds.) (1977) *The Essential Piaget: An Interpretive Reference and Guide.* New York: Basic Books.
Mascolo MJ and Fischer KW (2005) The new constructivism: The dynamic development of psychological structures. In: Hopkins B, Barre RG, Michel GF, and Rochat P (eds.) *Cambridge Encyclopedia of Child Development*, pp. 49–63. Cambridge, UK: Cambridge University Press.
Stern DN (1991) *Diary of a Baby.* London: Fontana.
Vygotsky LS (1978) *Mind in Society: The Development of Higher Psychological Processes.* Cambridge, MA: Harvard University Press.
Wellman H (1992) *The Child's Theory of Mind.* Cambridge, MA: MIT Press.
Wellman H, Cross D, and Watson J (2001) Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development* 72: 655–684.

Relevant Websites

http://www.gse.harvard.edu – The Dynamic Development Laboratory.
http://www.lectica.info – The Lectical Assessment System for Skill Complexity.
http://naeyc.org – National Association for the Education of Young Children.
http://www.unige.ch – The Jean Piaget Archives.
http://www.piaget.org – The Jean Piaget Society.
http://www.marxists.org – The Lev Vygotsky Archive.

Cognitive Developmental Theories

G S Halford, Griffith University, Brisbane, QLD, Australia

Glossary

Cognition – Includes thinking, language, learning, memory, and perception.
Epistemology – Theory of knowledge.
Natural kinds – Things that occur in nature, such as plant and animal categories. As children mature their understanding of the world and their ability to reason about it both increase to a remarkable extent. Cognitive developmental theories are designed to account for this process. There were important pioneering theories by Piaget and Vygotsky, whose ideas are still influential, but their ideas have been incorporated into a number of new theories, which we will outline.
Prototypic category – One based on the most typical example of the category (e.g., a prototype of the dog category would be the most typical dog). Prototypes are acquired automatically by exposure to examples of the category and are possibly the earliest categories to develop.