

STEVENS' HANDBOOK OF EXPERIMENTAL PSYCHOLOGY

THIRD EDITION

Volume 3: Learning, Motivation, and Emotion

Editor-in-Chief

HAL PASHLER

Volume Editor

RANDY GALLISTEL



John Wiley & Sons, Inc.

/ 2002

CHAPTER 10

Role of Learning in Cognitive Development

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The role of learning in cognitive development has been conceptualized in three different ways. From a purely empiricist perspective, cognitive development is learning. A general-purpose learning process—association formation—is the process through which the structure of experience forms the structure of the mind. The only developmental constraints on knowledge acquisition are whether the capacity to form associations between elementary sensations, or between sensations and responses, is in place. If one's sensory systems are immature or not functioning, or the capacity to form associations is weak, then little or no cognitive development can occur. The structure of the associative learning process is independent of the structure of the material being learned. There are no a priori data-organizing principles. The mind of the infant is a blank slate (*tabula rasa*), and "The senses at first let in *particular* ideas, and furnish the yet empty cabinet. . . ." (p. 72; Locke, 1690). The same learning process operates throughout development and for all domains of understanding. This assumption is shared by a range

of theories grounded on general processes (Rumelhart & McClelland, 1986; Siegler, 1991; Skinner, 1938, 1950).

Stage theories, on the other hand, assume that the structure of the child's mind passes through a sequence of qualitatively different stages and that the structure at a given stage determines what can be learned at that stage (Bruner, 1964; Piaget, 1970). In stage theories, the mind is active and constructs reality. It goes in quest of particular experiences, rather than passively registering the associations that it happens to encounter. The experiences it seeks are those that will nurture its development to the next structural stage through the processes of assimilation and accommodation.

Although the structure of the mind at a given stage determines what can be learned, the structures of the successive stages are not domain-specific. They govern what can be extracted from experience in any domain. For example, Piaget's stages are about sensorimotor schemata during infancy and concrete logical operations during the school-aged years. Within this theoretical framework, infants at the beginning of the sensorimotor period of development cannot form stable perceptions of objects, social or otherwise. A fortiori, they cannot form concepts about objects within domains, such as physical objects or social objects. Instead, they start

Authors are listed in alphabetical order. The preparation of this chapter was partially supported by NSF grants DFS-9209741 and SRB-97209741 to Rochel Gelman. The authors are especially grateful to their editor for his input and editing suggestions.

responding reflexively to particular stimuli; then, with continued use, these reflexes are gradually adapted to form what are called primary circular reactions as opposed to reflexive ones to these stimuli. These in turn are used repeatedly and become interrelated and coordinated, and so on.

Although infants actively engage whatever objects are placed before them, it is assumed that they have no memory for these. The idea is, if out of sight (or touch or hearing range), out of mind. Thus, Piagetian theory shares with the general learning theory the position that it will take a great deal of time before infants can be granted the concept of an object that exists in a three-dimensional space and independently of the infants' own actions. Even after several years of mental development, preschool-aged children are assumed to be perception-bound and unable to form consistent classifications. The result is that they are unable to form abstract concepts. Thus, the stage theory perspective shares with the general learning theory the assumption that cognitive development proceeds from elementary experiences to abstractions, and that this progression takes a long time. Haith and Benson (1998) recent treatment of infant cognition has much in common with this position.

In recent decades, a third perspective has come to the fore; this may be called the rational-constructivist perspective. It assumes that learning is guided from the outset by domain-specific principles (hence, the "rationalism"). These principles enable the child to construct a representation of the world from experience (hence, the "constructivism"). This perspective explains a range of new experimental findings, which is a key reason for our discussion to focus on this approach and its account of cognitive development and learning.

The rational-constructivist perspective recognizes a fundamental truth at the heart of the Piagetian perspective, which is that children

are active participants in the construction of their own cognitive development. However, learning is not a homogeneous or content-neutral process. Rather, it is made possible, at least to start, by different sets of core or domain-specific skeletal principles that direct the infant's attention to relevant aspects of experience and organize the resulting experiences (Baillargeon, 1995; Carey, 1985; Cosmides & Tooby, 1994; Fodor, 1975, 1983; Gallistel & Gibbon 2000; Gardner, 1992; Hirschfeld & S. Gelman, 1994; Keil and Wilson, 2000; Leslie, 1995; Spelke, 2000). Hence these principles foster domain-based early learning (even in infancy). Such learning is rapid, universal, and non-reliant on instruction (cf. Chap. 11 this volume for a documentation of this in connection with the learning of language).

The rational constructivist perspective, moreover, can account for a developmental function in learning. This developmental function is evident in three kinds of later learning that contrast with early core learnings in terms of rapidity, ease, universality, and reliance on instruction. One kind of later learning can be characterized as "core-consistent knowledge extension." This later learning is domain-based because what is to be learned is consistent with and hence builds on the core knowledge or skeletal principles in a domain. It is very similar to initial learning in being relatively rapid and easy. This kind of later learning will be considered in this chapter. Second, later learning can represent "core-inconsistent knowledge acquisition." In these cases, what is to be learned might appear to be related to core knowledge in a domain, but is inconsistent with one or more core principles. Hence, while domain-related, the learning is not based on a known knowledge structure. This learning is very dissimilar to early learning in being effortful, protracted, and non-universal. Examples of this kind of later learning also will be discussed in this

chapter. Finally, there are those cases where later learning involves totally new domains, ones unrelated to core domains of knowledge. Learning sushi-making and air traffic control are cases of such later learning. This chapter does not address later learning of this kind.

This discussion of learning in cognitive development, based on the rational constructivist perspective, presumes a variety of learning tools that the mind recruits in the service of knowledge acquisition. The kind of tools that are recruited, be it for early or later learning, can vary depending primarily on whether what is to be learned is consistent or inconsistent with the skeletal principles in a domain.

We move first to a general discussion and overview of the rational-constructivist view of cognitive development and learning. This entails review of the concepts of domain (core and noncore), of the skeletal nature of early principles, and of the description of mental learning tools. We follow this with a discussion of learning in three domains—physical objects, number, and sociality—with more emphasis on the latter. Early and later learning will be examined. Cases of later learning that are “core-consistent” will be contrasted with cases that are “core-inconsistent.”

WHAT IS A DOMAIN?

A given set of principles, the rules of their application, and the entities to which they apply together constitute a domain (e.g., R. Gelman, 1993; see also Gallistel, 1990). Different domains are defined by different sets of principles. Therefore, we can say that a body of knowledge constitutes a domain of knowledge if we can show that a set of interrelated principles organizes its rules of operation and entities. Sets of principles carve the psychological world at its joints, producing distinctions that guide and organize our reasoning about entities in one domain versus

another. In this way, available domain-specific structures encourage attention to inputs that have a privileged status because they have the potential to nurture learning about that domain; they help learners find inputs that are relevant for knowledge acquisition and problem solving within that domain.

Core and Noncore Domains

Nothing in the above definition of domain-specific knowledge structures speaks to their origin. Although some knowledge domains benefit from foundational skeletal structures, many do not (Bransford, Brown, & Cocking, 1999; Karmiloff-Smith, 1992). To emphasize this, R. Gelman and Williams (1998) distinguished between *core* and *noncore* domains. The class of core domains is simply those that are universally learnable with relative ease.

The distinction between core and noncore domains is analogous to the linguistic distinction between closed and open class morphemes. All who acquire language as young children share knowledge of the small set of closed class of morphemes in that language. These morphemes serve the capacity to generate utterances that honor the combinatorial rules underlying the syntax of the language. The open class of morphemes includes all learned and to-be-learned nouns, verbs, adjectives, and adverbs—potentially an infinitely large class. Different individuals can master different examples and different numbers of entries in the open class. Similarly, the set of noncore domains is potentially very large and can vary from individual to individual. In contrast, the set of core conceptual domains is relatively small, and their underlying structures are shared by all (R. Gelman & Williams, 1998).

As in the case of different languages, there are some underlying common structures even though different cultures might differ in the particulars that make up the domain-relevant

knowledge. For example, as far as we can tell, everyone all over the world makes a distinction between animate and inanimate objects that are separably movable. Still, there exist notable differences in how rich a knowledge structure about animals a given culture achieves (Hatano & Inagaki, 1999).

Early Learning/Competencies

The idea that core domains serve as learning devices provides an account of the fact that young learners respond to structured data as opposed to simple punctate sensations. The reason is that application of even skeletal structures means that the class of relevant data will be relational and overlap with the abstract principles that lime the domain. This means that those infants need not be confronted with William James' "blooming buzzing" confusion of punctate bits of uninterpretable sensations. Instead, they can behave as if there were an environment with physical and social things "out there"—things to find, interact with, and learn about. Different implicit knowledge structures should encourage attention to and exploration of different kinds of structured data, and assimilating these helps nourish the coherent growth of these nascent structures.

The metaphor of a skeleton helps to clarify the notion of innate principles. If there were no skeletons to outline the shape and contents of the bodies of the pertinent mental structures, then there would be no reason for young learners to select domain-relevant experiences, let alone store those experiences in a coherent way. Just as different skeletal structures are assembled according to different principles, so too are different coherent bodies of knowledge. Skeletons need not be evident on the surface of a body. Similarly, the underlying axiom-like principles, which enable the acquisition of coherent knowledge, need never be explicitly accessible. Many principles that

organize language learning, for example, are deeply inaccessible (see Chap. 11, this volume). Most importantly, skeletons lack flesh and some relevant body structures. Thus, they are not full-blown explanatory theories, as suggested by Gopnik and Meltzoff (1997). They are information-structuring principles that need to interact with the kinds of environments that nourish and support domain-relevant conceptual development.

In the history of developmental biology, this kind of account of development is called epigenetic, in contrast to the preformistic account that it superseded. In epigenetic development the final structure is not present at the outset (performed); it develops through an interaction between an initial genetic structure and relevant environments. Eyes are not performed in embryos. They emerge through an epigenetic process that is guided by a hierarchy of genes specific to eye formation. Similarly, the grammar of a specific language is not performed in the mind of the newborn baby. It develops in the mind of the young child from its experience with its linguistic environment, guided by a hierarchy of language-specific principles (see Chap. 11, this volume). In a related way, skeletal structures for different core domains serve to guide the epigenesis of the domain (cf. Scholl & Leslie, 1999). Like language, the surface structure of the knowledge that emerges differs from one locale to another, but these different surface structures share underlying domain-specific principles. For an explanation of how this perspective accounts for the development of religious beliefs, see Pascal Boyer (2001).

Later Learning

It helps to distinguish between three kinds of later learning in development. The first constitutes those cases in which learning is about structurally consistent acquisitions. Hartnett and Gelman's (1998) treatment of the

successor principle for natural numbers—that every natural number has a successor—is an example of this kind of learning. This is an example of *core-based* knowledge extension. Two kinds of later learning do not readily build off existing core knowledge structures. One involves those concept acquisitions that appear related to what is known but upon careful consideration are not. This is because the “structures” of what is to be learned differ or even contradict the structures of already acquired concepts. Rational numbers constitute an example of the former because the principles that organize their domain are different from those for natural numbers. For example, because there is an infinite number of numbers between any pair of natural numbers, a rational number (e.g., a fraction such as $1/4$) has no specifiable successor number. We dub this kind of subsequent learning *core-inconsistent*. The learning that occurs here is clearly built on the easily mastered core knowledge, but it depends on the mounting of a new structure. In the same vein, the counterscript structures for representing ironic situations violate the principles of social scripts (that is why they are counterscripts). Hence, the mastering counterscripts for the understanding of ironic events is another example of core-inconsistent learning and development.

Finally, there are the cases in which people must master bodies of knowledge that seem unrelated to any core domains. These kinds of later learning are often discussed in the expert-novice literature on chess, history, algebra, economics, literature, and so on.

Both of the latter kinds of subsequent learning present comparable challenges to individuals because there is no domain-relevant skeletal structure to start the learning ball rolling. The relevant mental structures must be acquired *de novo*, which means that learners acquire domain-relevant structures as well as a coherent base of domain-relevant knowledge about the content of that domain (see also

Brown, 1990). It is far from easy to assemble truly new conceptual structures (Bransford et al., 1999; Carey, 1991; Chi, 1992; Kuhn, 1970), and it usually takes a very long time. Something resembling formal instructions is often required, and even still this is not effective unless there is extended practice and effort on the part of the learner (Bransford et al., 1999). In both cases, the later learning might even be at risk because learners may assimilate inputs to existing conceptual structures even when those inputs are intended to force accommodation and conceptual change (R. Gelman, 1993, 1994; Slotta, Chi, & Joram, 1995). That is, learners may fail to interpret novel inputs as intended and instead treat the data as further examples of the kinds of understanding that they have available.

The theoretical account of how later learning can occur should cover both core-inconsistent and noncore kinds of domains because in both cases a new conceptual structure must be mastered. A theory that involves learning tools for structural learning can accomplish this goal.

LEARNING TOOLS

Structure Mapping

Within the associationist framework, elementary sense data are the primary data for early concept learning. By contrast, within the rational-constructivist framework, basic experiences are defined in structural terms, by the relations exhibited. A domain's organizing principles lead learners to attend to relations when interacting with the world. This is not to say that sensory data are irrelevant but rather to say that, by themselves, they do not serve to get learning about concepts off the ground. Instead, babies and young children use the abstract principles from a domain to find, organize, and assimilate

domain-relevant, organized inputs. This follows from the assumption that principles of a domain encourage attention to domain-relevant data, that is, data that share a common structure with the domain's principles. In core domains, the skeletal principles themselves define initial representations that become the repository of all data whose structure can be mapped to them. Structure mapping serves learners' abilities to identify relevant inputs when going beyond old learnings, given the ever-present tendency to apply existing mental structures to new learning.

Like others, we assume that learning leads to the buildup of a richer conceptual structure within a domain. R. Gelman and Williams (1998) couched their account of learning in terms of the kinds of mental learning tools that can contribute to the active construction of knowledge. They argue that the mind favors *structure mapping* as the fundamental learning process. Given that the mind actively applies its existing structures to find examples of structured data in the environments with which it interacts, learning in core domains is privileged. Skeletal structures provide the beginning learner with the wherewithal to find and map inputs that are examples to available structures. This leads to the enrichment of those structures.

Analogical Reasoning: A Variant of Structure Mapping

Learning by analogy involves finding a correspondence between two events, domains, or examples and then transferring what is given or understood about one case to the other case. For example, Inagaki and Sugiyama (1988) asked children ranging in age from 5 years to 10 years about a number of biological characteristics of living kinds. They first obtained similarity-to-people judgments. The children rank-ordered rabbits, pigeons, fish, grasshoppers, trees, tulips, and rocks and used

this similarity ranking to assign predicates such as "breathes," "has a heart," "can think." Obviously, analogical reasoning by itself will not suffice to guarantee acquisition of correct knowledge. For example, a grasshopper—no matter how small and different looking when compared with a person—does breathe. A key consideration in the success of analogical reasoning is the choice of the analogy.

There is an emerging consensus that successful analogical transfer depends on the extent to which structure mapping is possible. The probability that transfer will occur is very high if learners achieve representations that are structural isomorphs but very low if learners must rely on surface cues of perceptual similarity (Brown, 1990; Gentner, Rattermann, & Forbus, 1993; Goswami, 1995; Holyoak & Thagard, 1995). For instance, by taking advantage of very young children's principled knowledge about causality, Goswami and Brown (1990) were able to illustrate that children solve analogies of the $a:b::c:d$ form when a common causal transformation forms the basis of the analogy. In another example of analogical reasoning and transfer, Catrambone and Holyoak (1989) presented subjects with multiple analogous word problems and measured transfer to the solution of a superficially different word problem; transfer was facilitated when the problems were worded to emphasize their structural similarities.

Imitation and Template Matching

Imitation is a way to learn by watching and listening to others. It clearly depends on an ability to form a representation of a model that embodies key aspects of what is being done. Meltzoff and Moore's (1983, 1989) work on imitation makes it clear that even infants learn new event sequences by watching others perform them. It is hard to overestimate the significance of this learning tool. It

provides learners a way to acquire new knowledge schemas at negligible cost and then to use these to monitor the quality of their output. This phenomenon is well known to piano players. Often, they listen to a record by a great master to get a better model of how a particular piece can be played. Then follow hours of practice, with the pianists stopping, starting over again, stopping, and so on, often shaking their heads and indicating that their performances are not matching the models in their heads. Significantly, the fact that the mind monitors the output generated by a given mental structure means that there is an on-line way to get feedback about the degree to which learners have achieved their learning goals—a match of their knowledge and skill to what their models set as the standard.

In some cases it is reasonable to conclude that a young learner starts with a template, that is, a sketchy model of the kind of data and performance opportunities that are needed to tune the given template. Marler's (1991) work on birdsong learning in the male song sparrow provides an excellent example. Songbird-learning mechanisms are specific adaptations that are designed to operate in environmentally specific contexts to ensure the uptake of information that is essential to the later reproductive success. Innately determined song templates guide selection of what is to be remembered to serve as the model for later practice. Of major interest here is the fact that song sparrows that grow up in different places sing different songs, namely, songs with the characteristics of the local dialect to which they are exposed plus individual signature elements. White-crowned sparrows, like many songbirds, have a sensitive period somewhere during the first year of their life. If they do not get to hear the song of an adult sparrow during this time, the song they sing will be decidedly odd when they grow up. The sensitive period has the effect of tuning the bird's template for a particular class of song.

Exposure during an early period of life does not, however, suffice to guarantee that the young bird will grow up to sing the represented song, or that its adult song will be normal. The bird must go through periods of subsong learning and crystallization, again during the first year of life. The subsong learning period is especially interesting for us because only at this time (after the sensitive period for exposure) does the young bird start to sing. The initial efforts in this period look very much like a trial-and-error series and in some ways are like an infant's babbling; the song sounds not at all like the adult target model. The data gathered by Marler and colleagues suggest that the bird is working at converging on a particular output plan, which generates a song that is consistent with the song template that is mentally represented. Without any more input than what the young bird produces at this point, the bird gradually moves toward singing a song that contains more and more notes and phrasal units of the adult song (Marler, 1991; D. Nelson & Marler, 1993). It is hard to resist comparing the young white-crowned sparrow's learning path with examples of children's learning. A case that we take up later comes from beginning language learners' efforts to master the count list of their language.

Pattern Detection and Learning

Work on perceptual learning (see Chap. 7, this volume) highlights another learning tool: pattern detection across multiple, different examples of the target. Kellman (1996) shows that this kind of perceptual learning can facilitate the acquisition of knowledge about mathematics and airplane controls. In Kellman's studies, individuals are not drilled with repeated exposure to the same examples; instead, numerous and *different* instantiations of a complex situation are presented. There are theoretical reasons for this choice. By

presenting different examples of the same structure, individuals encounter opportunities to separate relevant from irrelevant aspects of the display. This is related to the fact that there are opportunities to compare and contrast examples. Such considerations are well known to students of Gibson's (1969, 1984) theory of perceptual learning. They also were important in R. Gelman's (1969) choice of conservation training materials. Together, the different examples provide learners with an opportunity to rule out the irrelevant features of any one particular example and abstract the conceptual structure that generates the examples.

The foregoing description shares many of the ideas regarding the centrality of structure in new learning. For this reason, one should expect individuals to recruit pattern detection abilities when the data for new learning constitute multiple and different examples of the principles that organize a domain.

Contingent Frequency Computing

Skeletal principles in core domains draw attention to the class of relevant inputs and organize the assimilation and early representation of noticed cases. Skeletal structures start to accumulate flesh as structured examples are assimilated. In addition, they take advantage of an automatic (i.e., nonconscious) ability to keep a running frequency count of encountered exemplars and their relevant aspects. Such a learning tool contributes to the buildup of knowledge of the predictive validity of the different attributes of encountered exemplars. For example, certain surface properties and form attributes characterize animate objects, as opposed to different properties and attributes, which characterize inanimate objects (R. Gelman, 1990; S. Gelman & Opfer, 2001).

The registration of attribute frequencies and the computation of their predictiveness (i.e., of the contingency between a given concept and the possession of a given surface

attribute) are carried out by what we call a frequency/contingency learning tool. It is a good example of the middle ground, described earlier, between domain generality and domain specificity; it operates specifically on frequency data, but it also performs the same frequency-computing function in many different conceptual domains.

There is good evidence that animals and humans of all ages keep track *automatically* of the frequency of relevant events, objects, words, and grammatical units (Aslin, Saffran, & Newport, 1998; Gallistel, 1990; Marcus, Pinker, Ullman, Hollander, Rosen, & Xu, 1992; Saffran, Aslin, & Newport, 1996; Watson and Ramey, 1987; Zacks & Hasher, 2001; see Chap. 11, this volume, for the fundamental role this plays in the learning of language).

For example, Hasher and Zacks (1979) showed children ages 5 through 8 a series of pictures, in which each picture appeared zero to four times. Afterward, children in all age groups were highly and equally successful at reporting how many times a picture had been shown, even though they received no instructions to keep track of this information. Similarly robust abilities to pick up frequency information about objects or events abound. Marcus et al. (1992) document people's ability to keep track of the different frequencies of irregular past tense and plural words. Infants keep track of frequencies of items or events of interest, including the number of times they have to suck on a pacifier or turn their head to achieve presentations of sounds, well-focused photographs, and the movement of a mobile (Rovee-Collier & Bhatt, 1993; Watson and Ramey, 1987).

People know that black is the most frequent color of limousines, that red is the preferred color for fire engines, that white and green are the colors commonly worn by people who work in hospitals, and so on. Perhaps more surprising is Macario's (1991) finding that preschool children who could play his

"what will we take on a picnic" game were able to generate possible foods on the basis of a color cue. All of these examples feed Zacks & Hasher's (2001) proposal that learning about the frequency of *noticed* objects and events is ubiquitous and well as and Tversky and Kahneman's assumption (1973) that we can use base rate information in making judgments.

These lines of evidence contribute to our assumption that humans and animals make use of an implicit frequency computational device as an extremely potent learning tool. Gallistel (1990; Gallistel & Gibbon, 2000) reviewed evidence that animals in classical and instrumental conditioning paradigms are learning the rate/frequency of reinforcement and its contingency on available cues, rather than the ever stronger associative pairings predicted by associationist theory. From raw frequencies the animals are computing contingencies, that is, the extent to which the frequency of reinforcement in the presence of a conditioned stimulus is different from the frequency observed in its absence. As with humans, these computations are automatic and continuous.

Some readers may misunderstand the idea that contingent frequency computation is a learning tool. Indeed, the report of infants using statistical information about language has been erroneously taken to mean that language learning is not based on an innate domain-specific structure. The claim is that the ability to register frequency information supports a general learning mechanism, one that is indifferent to the structure of different domains (e.g., Elman et al., 1996), in the spirit of the general-purpose learning process of radical empiricism (as elaborated, e.g., in Chap. 2, this volume). This is an unwarranted conclusion. It fails to recognize the significance of granting the mind the ability to represent frequency and do so selectively, that is, with respect to whether such information is recruited for a given type of knowledge acquisition.

If it is, the mind must have a way to recognize that it would help to learn the frequency with which certain kinds of events or objects occur. There is nothing about frequency information itself that says "I am here to tell you about animal kinds and their colors," "I am here to tell you about events forming a script about them," or "I am here to enable you to extract the grammatical function of this word." Whether a frequency-tracking device should be engaged depends on the nature of the mental structure guiding the learning. Hence, *contingent* frequencies are stored.

There is another reason that it is an error to slip from the fact that the mind records frequency to a variant of an associationist, rule-free model of acquisition. Within the framework of an association model, frequency is one condition for the accrual of association strength. It is the associative strength (or weight of a connection) that is represented, not the condition that led to its strength. That is, there is nothing in the association that preserves the conditions that influence its strength, be these frequency or contiguity of pairings. In our view, the foundational structure in core domains always comes from the skeletal principles embodied in enabling constraints; frequency data about relevant encounters are *subsequently* recorded and attached to that existing framework. Frequency information does not help the learner to recognize encounters in the first place. How such frequency information is used depends on the domain in question. Individuals will not say that an irregular verb that has a high frequency is a better example of verb than is a relatively novel example of a verb with a regular past tense (Marcus, 1996; Pinker, 1991). Many different factors combine to determine associative strength, but the factors contributing to that strength (e.g., frequency) are not represented by associative strength and therefore are not recoverable as inputs for learning.

In sum, the frequency-counting computational device is a mental learning tool and not a variant of the law of frequency governing the learning of associations. If learners take advantage of a frequency-computing device, they have a way of learning that some features of objects have predictive validity, even though they are not defining (Macario, 1991). For example, although the color red has high predictive validity for a tomato, it is not defining. There are yellow tomatoes. Worse yet, there are other foods that have a high probability of being red. Similarly, the distinction between a rigid versus malleable form is strongly correlated with the animate-inanimate distinction, but does not determine it. To be sure, the rigidity cue has considerable predictive validity for animacy/inanimacy, as do attributes such as uniform versus variable surface textures, motion paths, and the presence or absence of limbs, eyes, ears, and so on. Although not one of these is defining, it still helps to learn their relative frequencies and related contingencies. Such computations allow us to make informed guesses about the animacy status of a novel or unidentified item, and then check to see if the guess is consistent with the requirements of the domain. Informed guesses can be disconfirmed by subsequent information, which violates core principles about a domain; no matter how much something looks like a rock, we will no longer believe it to be a rock if it gets up and walks away. And no matter how unlikely a particular example of a category might be, we can accept it if it can be assimilated to the domain's principles. Thus, a green lemon with writing on it is still a lemon, and a three-legged cat is still a cat.

The proposal that a mental learning tool computes the frequency of relevant encounters converges with conclusions drawn by other authors. Schwartz and Reisberg (1991) suggested that we may need a three-part

theory of concepts in which "concepts are represented by a prototype, some set of specifically remembered cases, and some further abstract information" (p. 391), where all parts interact to accomplish correct similarity judgments and inferences. In our account, the recorded knowledge of frequencies and contingencies underlies subjects' abilities to answer questions in ways that make them look like they learn prototypes and some salient domain-relevant exemplars. Armstrong, Gleitman, and Gleitman (1983) concluded that we know the difference between saying an object is an instance of a concept versus characterizing it as a good or bad instance. More generally, our account provides a way to reconcile these response patterns with the compelling arguments against the idea that our concepts are based on prototypes (Fodor & Lepore, 1996).

Converging lines of thought exist with respect to children's understanding of causality. Bullock, Gelman, and Baillargeon (1982) argued that causal principles lead children to search for causal mechanisms and assimilate causally relevant information about events, including the cue value of spatial and temporal cues. Ahn, Kalish, Medin, and Gelman (1995) concluded that information about covariation and causal mechanisms plays complementary roles in our decisions about causes. Cheng (1997) showed that people relate their computations of contingency to their beliefs in causal principles.

Metacognition

The term "metacognition" is used to refer to a host of processes, including monitoring, self-correction, planning, thinking about one's knowledge, engaging in thought experiments, and so on (for further discussion see Brown, Bransford, Ferrara, & Campione, 1983; Bransford et al., 1999). We agree with

Brown et al. (1983). It is a mistake to lump all these processes under one umbrella.

Monitoring and self-correction can be seen in very young children; indeed they are expected given a constructivist theory of learning and therefore the active involvement of even young learners in their own cognitive development. Very young children have potent tendencies to keep at an act, be it throwing a cup off the table, climbing steps, 'rehearsing' the language they are starting to acquire, self-correct their counts, and so on. These activities are best thought of as on-line monitoring and self-correction. As crucial as they are, they surely are of a different kind than are those that involve active planning or pondering the nature of one's knowledge of about language, sociality, mathematics, etc. We therefore follow the convention of treating meta-cognition as a process that cannot be engaged unless the individual already has acquired either a knowledge base and (or) some problem-solving strategies.

Our emphasis on the difference between domain-specific and domain-general learning tools has implications for a discussion of meta-cognition. First, there should be different kinds of meta-cognition, for example, ones that are domain-relevant and ones that are domain-independent. Problem-solving strategies like "take the problem apart" are examples of the latter. Thinking about one's domain-based knowledge is a case of the former. Thus, whether there is another natural number after a googol requires pondering the consequences of addition and whether one can make up new count-words. This involves an ability to reason about the domain-specific consequences of arithmetic. Similarly, when we turn to thinking about the domain of sociality, we are thinking about social rules. Now the meta-cognition involves thinking about social rules and different ways to violate or play with them. As we shall see, there are different kinds

of meta-cognition—even within the sociality domain.

Re-Representational and Technological Tools

Human knowledge acquisition benefits from the ability to create and use re-representations. A re-representation represents in a culturally determined format something that has a more basic or more primitive, purely mental representation. Examples of re-representational tools are spoken and written language, drawings, maps, mathematical and musical notations, and so on. Similarly, man-made tools of both simple and complex varieties offer rich opportunities to go beyond what is based on core domains. Not only do young children benefit from the ability to develop language, but they quickly start to catch on to the role of tools and some re-representational formats as well, including those involved in television and computers. Given a supporting culture, young children catch on to the fact that there are different rules for different notation systems, even though they have much to learn about the details and conventions for these (Brenneman et al., 1996).

Learners' proclivities to map available structures to environments help to explain what might seem like a rather precocious ability in young children. Before they are taught to write, they can generate different plans of action in response to a request either to write a word or to draw a picture for a given line drawing (Brenneman, Massey, Machado, & Gelman, 1996); they can develop writing systems (Tolchinsky-Landsmann, 1990); and they can distinguish between a string of marks on paper that are "good for writing" as opposed to "good for numbers" (e.g., Lee & Karmiloff-Smith, 1996). How do the young even begin to sort out the fact that there are different kinds of "marks on paper"?

Gelman and Brenneman (1994) argued that young children's structure-mapping tendencies serve them in this case as well as those discussed already. The idea is that each of the symbol systems has its own structure and related constraints. For example, we know that young children have implicit knowledge about the structure of inanimate objects and language. The latter have bounded surfaces and are solid (as discussed later). Drawings of objects map these characteristics, at least often enough. An orange is drawn as a continuous circle and is filled in with the color orange. Language is represented as a sequence of sound units; print (at least in the cultures studied) consists of a sequence of marks with spaces between them, and so on. Such differences in structural relations do not begin to define the full range of our implicit knowledge about objects and speech, on the one hand, and drawing and writing conventions, on the other. Still, they might suffice from the viewpoint of young learners whose goal is likely to be limited to an attempt to distinguish between the kinds of marks on paper that they encounter. This goal can be served by their omnipresent tendency to engage in structure mapping. These young children's beginning representations of the difference between drawing and writing are hardly adequate. No matter. What matters is that they exist at all. Once they do, a learning path opens up. In the case of writing, they will encounter many adults who are eager to encourage and support their movement along it.

The tools of the information age have expanded the representational and communication formats that children live with. There can be no question that these influence children's learning paths; however, how they do this is very much an open question. We do not take up their potential as learning tools, it is clear that such cognitive amplifiers (Bruner, 1964) in this chapter, can open a host of learning paths.

Summary

Together, these structural tools can be viewed as learning tools for identifying what aspects of new information are relevant and what information about different domains should be treated as coming from different categories, events, and so on. They afford the mind ways of identifying relevant novel data sets and setting up new memory drawers in which to collect and keep together in memory the new domain-relevant knowledge. Over time, these memory drawers will start to fill up—most likely in an unorderly way given the lack of understanding about them. With continued interaction with inputs and informal or formal instruction about these, however, there will come a point where we will, so to speak, look into our messy memory drawers and organize them in a systematic way. How and when this happens are key research questions that are especially likely to inform understanding about the shift from novice to expert levels of knowledge.

THREE DOMAINS

Central to the rational constructivist perspective is the assumption that different knowledge structures derive from the different principles that guide learning in different domains. Tables 10.1 and 10.2 highlight this central assumption by making it clear that different entities, principles, and structures are involved in the three domains that we will now consider: the domain of physical objects, the domain of number, and the domain of social objects. Physical objects move only when acted on, whereas social objects move spontaneously. Agency is a key principle for reasoning in the sociality domain, but it plays no role in understanding the interactions between inanimate physical objects. Cardinal values (the numerosities of sets) are elementary

Table 10.1 The Different Principles and Entities Forming the Skeletal Structure of the Domains of Physical Objects, Sociality, and Number.

Domain	Objects		Number		Sociality
Entities	Objects		Cardinality		Persons
Principles	For object identification	For causal relations	For counting	For arithmetic operations	For person identification and social interaction
	Solidity: One object in a given place (in 3-D space)	External energy source (contact) No action at a distance (implicit mechanism)	One-one stable ordering Cardinal item indifference	Addition Subtraction Ordering	Agency Contingency Emotional evaluation
	Connectedness in place and through most motions	Order (cause before effect)	Tagging-order indifference		Mental states Fittingness

objects of thought in the number domain. Solidity and inanimacy are irrelevant.

Inanimate Physical Objects

Spelke, Breinlinger, Macomber, and Jacobson (1992) suggested that infants begin with the assumption that their environment is three-dimensional and composed of things that occupy space, persist, move as units independently of one another, and maintain their coherence and boundaries as they move. Two principles of object perception follow: Two surfaces will be perceived as bounding the same object if they appear continuous with one another or if they move together at the same time and speed along parallel paths in three-dimensional space, even if their connection is occluded. She also proposed that the principle of solidity was a fundamental organizing principle: Because the surfaces bounding an object are inviolate, one object cannot pass through another.

Five-month-old infants respond in ways that are consistent with the belief that one solid object, a rotating screen, cannot pass through another solid object, a block hidden behind the screen (Baillargeon, Spelke, & Wasserman, 1985). Spelke (1991) provided similar evidence with 3- and 4-month-old infants. In her initial habituation phase, a ball was held

above a screen and then dropped behind it, after which the screen was removed to reveal the ball resting on the surface of the table. This event sequence was repeated until infants habituated, that is, looked less than half as long as on the first trial. During the posthabituation test trials, the ball was again dropped, but when the screen was removed after the drop, the object was resting either on top of or underneath a novel shelf that had been placed surreptitiously into the display. For the latter case, the ball ended up in a familiar position, on top of the table. To get there, however, the ball would have had to pass through the shelf interposed between the dropping point and the table. Therefore, both of the post-habituation events were novel, but only the latter one (ball-on-the-table) was impossible. Infants looked longer at the impossible event.

A series of related studies conducted in the laboratories of Baillargeon and Leslie showed that infants' understanding of physical phenomena involves the principles that objects need support to keep them from falling, that objects are displaced when one moves into contact with another, and that objects need to be propelled into motion (Baillargeon, 1995, 1998; Baillargeon, Kotovsky, & Needham, 1995; Leslie, 1994).

Given the above findings from infants, it is not surprising that toddlers and preschool

Table 10.2 Event Structure for Sociocultural Events by Event-Kind.

Event-Kind	Causal Relations	Event Structure			Temporal-Spatial Relations	Example
		Emotive Structure	Person and Interpersonal Relations	Concordance & Reciprocity		
Script	$A_g \rightarrow G_0 \rightarrow \text{Act} \rightarrow \text{Out}_w$	Pos/Happy			Delimited context	Mary is having a birthday party. Her friends have come and brought gifts. She opens her presents and blows out the candles, and they eat cake. They play games, and then the kids go home.
Counterscripts: Fluke-Win	$A_g \rightarrow G_0 \rightarrow \text{Act} \rightarrow \text{Out}_L \rightarrow \text{Non-}G_0 \text{ Act} \rightarrow \text{Out}_w$	Pos/Happy		Concordance	Delimited context	Clown practices his trick, where cream pie hits him in face. At show, the trick doesn't work, and the kids boo him. Clown sadly walks away, when he slips on the cream into a bucket of water. Kids love the clown.
Planned-Loss	$A_g \rightarrow G_0 \rightarrow \text{Act} \rightarrow \text{self-inflicted Out}_L$	Neg/Sad		Concordance	Delimited context	Billy gets a telescope at his birthday. He wants to be sure nothing happens to it. So he leaves his party to put it in his closet. On the way, he trips and falls, breaking the telescope.
Fruitless Win-Double Outcome	$A_g \rightarrow G_0 \rightarrow \text{Act} \rightarrow \text{Out}_L \rightarrow \text{Out now irrelevant} \rightarrow \text{Out attainable}_{L\&w}$	Neg/Sad Neg/Sad		Concordance	Delimited context	The Smiths wake to a great day and decide to have a picnic. They do lots of preparing and then go all the way to the park. Just then clouds come up, and it starts storming. They drive home. Then the sky clears and the sun comes out.
Temporal-Imbalance	—	—		Mismatch	Across contexts (temporal)	Clumsy child grows up to be prima ballerina.

NOTE: A_g = Agent; G_0 = Goal; Act = Goal-based actions; Out = Outcome (W = Win or L = Loss); Pos = Positive; Neg = Negative.

children learn about cause-effect sequences more readily than they learn about other sequences (Brown, Kane, & Echols, 1986; Mandler & McDonough, 1996). They can apply their skeletal principles about the nature of inanimate physical causation to learn about particular cause and effect sequences (Bullock, Gelman, & Baillargeon, 1982; R. Gelman, Durgin, & Kaufman, 1995). For example, young children postulate a hidden mechanism when confronting what looks like a possible case of "action at a distance"—an effect of one inanimate object on another located some distance away. When Bullock and Gelman (1979) showed 3- and 4-year-old children an event that had a gap between the cause and the outcome (cf., Leslie & Keeble, 1987), they either inferred a mechanism ("when I wasn't looking, the ball slid over"), talked about magic, or made it clear that something was not quite right ("What? How did that happen? It's a trick, right?"). Young children produced predominantly external causal attributions for the motion of familiar inanimate objects but not for the motion of familiar animate objects (Massey & Gelman, 1988; S. Gelman & Gottfried, 1996). They are also rather good at making predictions about the effects of transformations (Bullock, Gelman, & Baillargeon, 1982; Wilson & Keil, 1998; Zur & Gelman, 2001).

The foregoing kinds of results about preschool competencies contrast dramatically with the children's explanations of causal mechanisms and the makeup of physical objects. Explanations of physical mechanisms require knowledge about electricity, mechanics, properties of different materials, and so on. All of these involve conceptual structures that are not among those at the core of the domain. And many require conceptual change or the acquisition of noncore domains (Carey, 1991; Gelman, Romo, & Francis, in press; Keil & Wilson, 2000). It is therefore no surprise that even undergraduates attending top

universities in the United States provide shallow explanations of causal mechanisms (Keil & Wilson, 2000). Indeed, it is likely that most of us would do the same even for cases that we live with every day. Unless one is a trained automobile mechanic, it is a fair bet that most adults can predict that their car will start without being able to explain why. All of this goes to make the point that early principles about physical objects do not guarantee that one will acquire scientific explanations of how these interact in complex systems.

For recent reviews of the extensive work in this domain from several different laboratories, see Keil and Wilson (2000).

Number

Rapid Initial Learning

There is some evidence that infants abstract discrete and continuous quantities. Such findings serve as one line of evidence cited in favor of the idea that principles of number and quantity make up a core domain. Importantly, there are other lines of converging evidence in favor of this conclusion. Cross-cultural findings about "street arithmetic," studies with developmentally delayed or disabled children, and comparative animal data all contribute to the conclusion that humans are endowed with skeletal principles that support attention to number and quantity as well as their role in arithmetic reasoning principles.

By 6 to 9 months of age, infants look preferentially at a 2-item or 3-item heterogeneous visual display depending on whether they hear 2 or 3 drum beats (Starkey, Spelke, & Gelman, 1990). Xu and Spelke (2000) reported that 6-month-old infants discriminate 8 versus 16 items, even when the density, size, and area of the displays vary. These quantity abstraction abilities are related to implicit principles of addition and subtraction. Wynn (1992) reported that 4-month-old infants are surprised when the number of objects they

expect (1 or 2) is different as a result of unseen, surreptitious additions and subtractions (Wynn, 1992, 1995). Keochlin, Dehaene, and Mehler (1997) replicated and extended the Wynn findings to show that it held even when the objects in a display were changing location.

Evidence that these effects of addition and subtraction are treated as number-relevant comes from Brannon's finding that 11-month-old infants make use of an ordering relation. To demonstrate infants' ability to attend to and learn about numerical ordering, Brannon (2001) first habituated infants to ascending or descending sequences of set sizes (e.g., 1, 2, and 4 and 2, 4, and 8, etc.). When tested with the novel values of 3, 6, and 12 items over six alternating ascending and descending trials, they showed a reliable tendency to detect the reversal in order. It remains to be seen whether younger infants will show a similar sensitivity to an arithmetic ordering. Whether they will or not, it is becoming clear that preverbal infants respond to abstract properties such as number and quantity as well as some simple arithmetic relations. This conclusion gains strength from studies showing that animals and adult humans probably share the same nonverbal mathematical structures for generating cardinal values and the effects of combining these with the operations of addition and subtraction (Gallistel & Gelman, 2000).

As illustrated in Table 10.1, nonverbal counting is part of a number-specific domain because the representatives of numerosity (what Gelman and Gallistel, 1978, dubbed numerons) generated by counting are operated on by mechanisms informed by, or obedient to, arithmetic principles. For counting to provide the input for arithmetic reasoning, the principles governing counting must complement the principles governing arithmetic reasoning. For example, the counting principles must be such that sets assigned the same

numeron are in fact numerically equal and that the set assigned a greater numeron is more numerous than a set assigned a lesser numeron. Importantly, there is nothing in this formulation that requires that counting be done with words. As long as the process that generates symbols for numerosity honors the one-one, stable, and cardinal principles and tolerates a wide range of item types, we can say that it is a candidate counting device. A pulse generator and a computer are examples of such entities. Data from children who have developmental disorders reinforce the idea that normal children benefit from a nonverbal core domain that involves counting and arithmetic principles that operate on their output.

Absence of Initial Learning in Some Impaired Populations

R. Gelman and Cohen (1988) compared the ability of preschool children and (older) children with Down syndrome who had similar mental ages to solve a novel counting problem. The use of a novel (unusual) counting task was motivated by considerations about the nature of transfer. Transfer is unlikely to occur if the original acquisition task did not yield understanding of the underlying conceptual structure. Even after intensive instruction, children with Down's syndrome have considerable difficulty with simple arithmetic tasks, including adding and subtracting, telling time, and shopping. From the core domain perspective, this suggests that these children lack the organizing principles that enable them to profit from relevant experience—even extensive experience. If so, despite repeated drill in counting, adding, subtracting, and ordering numbers, they might not achieve learning with understanding. R. Gelman and Cohen found that six of the eight children with Down's syndrome failed to solve the order-irrelevance task, a test of whether children behave as if they know that any item in an array can be tagged with any of the 1 . . . N tags that can be

placed in one-one correspondence as long as one and only one tag is assigned to each item (Gelman & Gallistel, 1978). The performance of the comparison group of preschool children far outstripped that of the Down's syndrome sample, both in terms of their ability to invent strategies and in terms of the ease with which they engaged the task.

Many of the children with Down's syndrome in the R. Gelman and Cohen (1988) study had a considerable amount of syntax (Fowler, Gelman, & Gleitman, 1993). Thus, one should be cautious about arguments that treat the mastery of semantic and syntactic rules as conditions of verbal counting (e.g., Carey, 1998; Bloom, 2000). This is especially so given that some individuals with low IQs have almost no syntax but are very good with numbers, as contrasted to others, who have extremely complex syntax but cannot count systematically (Grinstead, Swann, Curtiss, & Gelman, 2001). This kind of double dissociation in selected populations of impaired subjects is another reason to treat number as a core domain that is independent of language.

The children with Down's syndrome in the R. Gelman and Cohen study lived at home and attended an excellent school. They received extensive training in counting, money, time, and other numerical and arithmetic tasks. Nevertheless, they did not induce the counting principles. By contrast, there are normal children who do not go to school who engage in what is called street arithmetic (Nunes, Schliemann, & Carraher, 1993) or intuitive mathematics. Liberian tailors who have no schooling can solve arithmetic problems by putting out and counting familiar objects, such as buttons (Reed & Lave, 1979). Taxicab drivers and child fruit vendors in Brazil invent solutions that involve different ways of putting together (adding) and decomposing count numbers (Nunes et al., 1993). Such data fit well with the idea that individuals have a

number-relevant skeletal structure of the kind presented in Table 10.1.

Facilitate Re-Representational Learning

If one assumes that humans start out with a domain-specific set of numerical/quantity principles, a key question arises. To what extent, if any, does this facilitate acquisition of verbal and notational instantiations of counting and arithmetic principles? If structure mapping serves as a major learning tool, then nonverbal counting principles should facilitate children's ability to identify and start to learn to use the count list of their language. Preverbal counting principles provide a conceptual framework for helping beginning language learners identify and render intelligible the individual tags that are part of a list that is initially meaningless. It also provides a structure against which to self-rehearse counting trials as well as build an understanding of the words (R. Gelman, 1993). On the matter of self-rehearsal, because mastery of the verbal list involves committing to memory a specific, long ordered sequence, it is unlikely that beginning learners will accomplish this task in one trial. If they indeed attempt to match input to a given structure, the structure can serve as a checkpoint against which to compare the output sequence with that required for counting. By analogy to Marler's young birds, the nonverbal structure is like a template against which one can determine whether the output is correct or wrong. Given that young counters do self-correct (Gelman & Gallistel, 1978), this is a plausible hypothesis regarding the way young children start to learn the count list of their language. It also fits with data indicating that beginning counters are far from perfect (Wynn, 1992) as well as the data presented above regarding children with developmental disorders. The reader should consult other accounts of the acquisition of verbal counting, ones that do not appeal to the idea that there is a mapping between

nonverbal and verbal counting (e.g., Bloom, 2000; Carey, 2000; Fuson, 1988).

It is one thing to master the language rules of a culture that make it possible to generate successive next numerals forever. First, even adults, unlike computers, do not readily memorize long lists of sounds that are not intrinsically organized. There is nothing about the sound "two" that predicts the next sound will be "three," or about the sound "three" that predicts that the next sound will be "four," and so on. This is a nonmathematical, information processing reason to expect the task of committing even the first nine count words to memory to take a considerable amount of time, and it does—as much as 2 to 4 years (Miller, Smith, Zhu, & Zhang, 1995).

The nonverbal counting process allows for the generation of a successor for each representation (the mind never runs out of numerons). To achieve the same in the verbal re-representation of number, the child has to confront a further serial learning problem. This is to master the often-complex base rules that are embedded in a particular language's counting system. The English count list lacks a transparent decade rule for at least the first 40 entries, and probably for the first 130 count words. Learning this rule takes a surprisingly long time. Hartnett (1991) found that a number of kindergarten and first grade students had yet to catch on to the procedure for generating the count words in the hundreds, most probably because many English-speaking children think that *one hundred* is the next decade word after *ninety*. In order for them to induce the hundreds rules in English, they need to encounter relevant examples of "hundreds."

Cross-cultural findings are consistent with this argument. Chinese has a more transparent base-10 count rule for generating subsequent count words, even for the tens and decades. Although the rate at which English- and Chinese-speaking children learn the first

nine count words is comparable, Chinese-speaking children learn the subsequent entries at a much faster rate (Miller et al., 1995).

This does not mean that English-speaking children are slower to recognize that every natural number has a successor; many 5-year-old children who have yet to master the base-10 generative rule acknowledge that nonverbal iterative processes can continue "forever" (Hartnett, 1991). A related phenomena was reported by Hartnett and Gelman (1998). They engaged children in kindergarten as well as in first and second grade in a thought experiment designed to encourage them to reach an explicit induction of the successor principle.

Ease of Learning Domain-Consistent Concepts

Hartnett and Gelman (1998) proposed that learning the natural number successor principle would take place with relative ease. In contrast, they expected children to have difficulty learning to understand the mathematical nature of fractions. These predictions were based on a consideration of whether children's principled understanding of counting and its role in addition and subtraction mapped to the principles that organize the to-be-learned concepts. In the case of the successor principle, the structure is completely consistent with those that make up the counting and arithmetic ones that organize their knowledge about natural numbers. This is not so for rational numbers.

Difficulty of Learning Domain-Inconsistent Numerical Concepts

The mathematical principles underlying the numberhood of fractions are not consistent with the principles of counting and the child's idea that numbers are rendered when sets of things are counted and that addition involves "putting together" two sets. One cannot count things to generate a fraction. Formally, a

fraction is defined as the division of one cardinal number by another. This definition solves the problem that there is a lack of closure of the integers under division. That is, if only integers are numbers, then, in general, it is not possible to divide one integer by another, because the result will not be an integer. To complicate matters further, some counting-number principles do not apply to fractions. Rational numbers (fractions) do not have unique successors; there is an infinite number of numbers between any two rational numbers. Thus, one cannot use counting based algorithms for ordering fractions, for example, $1/4$ is *not* more than $1/2$.

Neither the nonverbal nor the verbal counting principles map to a tripartite symbolic representations of fractions (two cardinal numbers X and Y separated by a line), but the formal definition of a fraction does. Related mapping problems have been noted by others (e.g., Behr, Lesh, Post, & Silver, 1983). Therefore, if children bring to their early school mathematics lessons their theory of number that is grounded in counting principles and related rules of addition and subtraction, their constructivist tendencies could lead them to distort fraction inputs to fit their counting based number theory. Early knowledge of number might therefore serve as a barrier to learning about fractions.

The Hartnett and Gelman findings were as expected. Even though the children did not receive lessons in school about the successor principle, they were relatively quick to take up the offered data and reach the conclusion that there always is a next natural number. The pertinent studies that were involved asked children to ponder a very larger number, then add 1 to that, then again add 1, and so on. Periodically, a child was asked if the number she or he was thinking about was the largest there could be or whether there were more numbers. Then, depending on children's answers, they were asked what the biggest number was

and whether they could add to it or what was the next number. Note that the interview does more than commandeer an existing knowledge structure. It encourages meta-cognition about the arithmetic principles and the generation of number words. No wonder that the children ended up talking to their friends and their parents about their new knowledge. The results regarding rational numbers make for a very different story, even though the children are taught about fractional representations and how to manipulate these arithmetically.

In one study reported in Hartnett and Gelman, children were asked to place number cards in order, on an "ordering cloth." After a pretest that included experience placing sticks of different lengths, demonstrations that some sticks could go at the same place, that it was okay to move items around, and naming of the numbers on each of the separate experimental cards, children were given the test items and then told to place these in order. The different cards had $1/4$, $1/3$, $1/2$, $1\ 1/2$, $2\ 1/2$, $2/3$, $2/4$, $2/2$, $3/3$, 0, 1, 2, and 3 on them. The results were striking: Not one child placed all cards correctly. They did not lack for inventiveness; they constructed a number of novel solutions. However, all of these involved treating the fractions as novel exemplars of counting numbers. For example, one child placed the fractional notations as follows: $1/2$, $1/3$, $2/3$, $2/4$. Some children separated the whole numbers into one category. No children recognized $2/2$ and $3/3$ as mathematical wholes (i.e., as equal to 1). Yet, it is essential that they eventually understand that this is the case and that they thus realize that the rational numbers include such entities. When put this way, it becomes clear that the everyday language of numbers does not provide the relevant stepping stone to learning. We do not go around saying, "You have two halves and I have three thirds, so we have equal shares." It is only in the language of mathematics that $2/2 = 3/3 = 1$. Of course, some children do go on to

master the arithmetic of rational numbers, but it is not difficult to find college students who lack an understanding of fractions (R. Gelman, 2000). The pedagogical task is to find learning tools that facilitate movement onto the relevant learning path, this being one involving mastery of the language and concepts of mathematics. In the next section we expand on the idea that learning tools can move cognitive development toward the goal.

SOCIALITY

This domain pertains to persons in social interactions. Hence, persons are the entities in this domain. As such, they are analogous to numbers and objects, which are entities in the domains of numerical reasoning (R. Gelman, 1998) and physical object knowledge (e.g., Spelke, Breinlinger, Macomber, & Jacobson, 1992), respectively.

Five principles guide the acquisition of social understanding: *contingency*, *agency*, *mental states*, *emotional evaluation*, and *fittingness*. These guiding principles are evident in the behavior of even very young infants. This is analogous to the principles of continuity and solidity guiding the infant's understanding of the world of inanimate objects and the principles of counting and integer arithmetic guiding children's understanding of number.

It is important to emphasize the skeletal nature of these principles. They are only implicit in the structure of the child's information processing system. The operation of these principles is tied to the input, that is, to the social interactions of the world. The young child is not thought to represent these principles conceptually any more than it conceptualizes the principles of a universal grammar (see Chap. 11, this volume). Put another way, the baby does not have conceptual command of these principles. One might best think of

the principles through a notation system of noncapital letters, such as the agency principle with a small "a" or mental states principle with a small "m" and "s."

The Privileged Status of Persons

Recognition of persons qua persons is fundamental. As in the other domains, evidence of the operation of this foundational abstraction appears very early in development. Persons tend to be imitated. Neonates imitate certain facial displays (Field, Woodson, Greenberg, & Cohen, 1983) as well as tongue protrusions, mouth openings, and head movements (Meltzoff & Moore, 1983, 1989).

Moreover, babies recognize persons as distinct from inanimate objects (Bonatti, Frot, Zangl, & Mehler, in press; Legerstee, Barna, & DiAdamo, 2000; Poulin-Dubois, 1999). For example, by two months of age in face-to-face interactions, infants respond differently to people (e.g., gazing, smiling, vocalizing) and objects (see Legerstee, 1992, for review). In addition, imitation is selective to persons. Five- to eight-week old infants imitate tongue protrusions and mouth openings modeled by an adult but not by an object (Legerstee, 1991). By ten months, differential exploratory behavior for novel objects and novel persons has also been demonstrated (Eckerman & Rheingold, 1974; Ricard & Gouin-Decarie, 1989). In exploring novel objects and novel persons (strangers), infant behaviors include longer approach time and more smiling and looking for the people.

Importantly, infants distinguish persons from other animals (Bonatti et al., in press). Hence, the distinction between humans and all other species of animals is as fundamental as the animate-inanimate distinction. Persons then are the basic entities in the sociality domain.

Also fundamental in this domain is an understanding of persons as social objects, hence

engaged with others. Persons participate in social interaction from the outset of life. Considerable data indicate that babies are social and that they engage in and respond to interaction with others from the start. Indeed, infants seem predisposed to social interaction.

Attachment behavior is a case in point. On ethological attachment theory, attachment arises from one of several species-typical behavioral systems evolved to promote infant survival (see Bowlby, 1969, 1973). This system motivates infants to seek the protective proximity of adults, especially when infants are distressed, alarmed, or in danger.

By 6 months of age, infants, at least on occasion, are influenced by the distal and proximal actions of their peers (Hay, Pederson, & Nash, 1982) and engage in successful attempts to interact, through vocalizations, smiles, and touches (Vandell, Wilson, & Buchanan, 1980). Infants, between 10- and 24-months of age, interact with their peers, exchanging smiles, vocalizations, and toys and imitating each other's actions (Eckerman, Whatley, & Kutz, 1975).

A biological preparedness for empathy has been proposed (Hoffman, 1975). The reflexive crying of infants in response to the crying of other infants has been interpreted as a primitive precursor of empathic arousal (Sagi & Hoffman, 1976; Simner, 1971). Furthermore, infants respond to the emotions of others: Certain emotion signals can elicit corresponding emotional states in infants, even in newborn infants. Sagi & Hoffman (1976) found that newborns cry in response to the sound of another newborn's cry and do so significantly more often than when they are exposed to silence or a synthetic newborn cry. Such responding has been found to be both peer and species-specific. Neonates are more likely to cry in response to a tape recording of another neonate's cry than in response to a tape recording of their own cry, an older infant's cry, or a chimp's cry (Martin & Clark, 1982).

Infants, nearly from birth, exhibit emotional responsiveness to other persons. Infants can perceive the emotions of others. Nine-month-olds express more joy and look longer at their mothers' joy expression and express more sadness, anger, and gaze aversion when watching an expression of sadness (Termine & Izard, 1988). Similarly, babies as young as 10 weeks discriminate between mothers' presentations of happy/joy, sad, and angry faces and match their mothers' emotions under some conditions (Haviland & Lelwica, 1987). Moreover, more than just simple matching of maternal expressions is evident in infant behavior. For instance, infants' responses to mothers' happy expressions represented a change in infants' affect state, rather than simple imitation. While infants' initial response to their mother's happy expression was to match or mirror that expression, infants became increasingly expressive of interest in the still positive interaction and less expressive of joy. Infants' responses to a maternal sad expression also demonstrated a change in infant state. Rather than matching the expression, infants showed more mouthing behavior, which is thought to be self-soothing.

Infants also show preferential attention to faces (J. Johnson & Morton, 1991; L. Nelson, 1987). Moreover, it has been proposed that facial expressions evolved specifically to convey social intentions and contingencies relevant to a specific audience (Darwin, 1859/1991; Fridlund, 1994). Indeed, facial expressions of emotion have been found to convey social messages with about as much consensus as they convey emotional ones (Yik & Russell, 1999).

Finally, the basic sociality of persons is evident in the universality of four social relationship types that people use to generate, understand, coordinate, and evaluate most social interaction (Fiske, 1991, 1992, 1993). These four basic types of social relationships are:

communal sharing; authority ranking; equality matching; market pricing. These relational categories are presumed to be intrinsic to the nature of mind.

These lines of data taken together make a compelling case for the basic sociality of persons. Granting social interaction as intrinsic to human functioning, the next section discusses evidence about the nature of its organization.

Evidence for Core Principles of Social Interaction

Five principles guide the acquisition of social understanding and represent initial albeit skeletal knowledge in the sociality domain. These are: *contingency*, *agency*, *mental states*, *emotional evaluation*, and *fittingness*. Although these are discussed sequentially, they are neither independent nor additive. Rather, the final principle is superordinate to the others in that it specifies an interrelation of the other principles. Hence, these principles exhibit a hierarchic organization.

Contingency

The principle of contingency concerns the relation between persons. It specifies that when two or more people are interacting, the actions of each should be contingent on the actions of the others. Role knowledge and role relations subsequently emerge from this early understanding of contingency and reciprocity in interpersonal interaction.

The game-like, formulaic routines of infancy, such as "peek-a-boo" and "wave bye-bye" are an indication of babies' understanding of and participation in reciprocal and contingent interactions.

Early mother-child interactive exchanges are contingent (Stern, 1985). Moreover, actions or behaviors of babies are time-linked to an object/person that moves or vocalizes in response to a baby's movement or vocaliza-

tions (Gergely & Watson, 1999; S. Johnson, Slaughter, & Carey, 1998; Watson, 1972).

Indeed, disruptions in social interaction, such as nonreciprocal or noncontingent interactions distress infants. In the first year, infants get upset when people do not behave actively and contingently or when they maintain a "still face" (Ellsworth, Muir, & Hains, 1993; Muir & Hains, 1993).

Toddlers coordinate behavior with that of a play partner (Baudonierre, Garcia-Werebe, Michel & Liegois, 1989), engage in communicative overtures in dyadic play (Ross, Lollis, & Elliot, 1982), and show interactional skills, such as coordination and alternation of turns, during games (Goldman & Ross, 1978). Moreover, toddlers show evidence of relationships, with reciprocal relationships predominating (Ross, Conant, Cheyne, & Alevizos, 1992). Further, toddlers engage in friendship patterns defined as complementary or reciprocal dyadic exchange and shared positive affect (Howes, 1983, 1988).

Contingency is also intrinsic to linguistic communication. It is apparent in the early linguistic exchanges between caretakers and children. Caretakers respond vocally to sounds, even such as burps, from babies (Snow, 1986). Moreover language use is guided by a contingency principle. Such a principle underlies Grice's (1975, 1978) maxim to be relevant and Sperber and Wilson's (1986) "relevance principle."

Agency

The principle of agency concerns the relation between persons and actions. It specifies that the actions of persons are goal-directed. Hence, persons are agents. Agents are described as decision makers, improvisers, or executive overseers (Russell, 1995) or as able to adapt, respond, and adjust to environments (R. Gelman, in press; R. Gelman et al., 1995) and to unforeseeable changes in circumstances (Gallistel, 1980).

An understanding of agency is not thought to develop from the abstraction of different types of motion characteristics, as proposed by Poulin-Dubois (1999). Indeed, R. Gelman (in press) has shown that the abstraction of motion characteristics alone is not sufficient for an understanding of agency. Rather, agency seems fundamental. An appropriate interpretation of motion characteristics requires that a concept of agency be in place already.

A notion of agency may be part of our biological endowment (R. Gelman, 1998; Leslie, 1995). Alternatively, or additionally, it may originate in social interaction. Such interaction is unpredictable or novel (Glick, 1978; Russell, 1995). According to Russell, agency originates in social interaction precisely because it is unpredictable. To deal successfully with others, the child must be a prodigious decision maker and must be on guard to select new but appropriate behaviors in light of what the other has done. The claim is that the most crucial ability for social life is the ability to improvise. Russell invokes the Norman and Shallice (1986) distinction between routine-action "scripts" and "supervising attentional systems." The latter, the executive overseer, takes control in novel situations. In social interaction there is constant novelty; new things are constantly being done. Hence, the supervisory system is in constant use.

Evolutionary arguments support the link between the complexity of the social world and the calculations to be done by an agent. The Machiavellian intelligence hypothesis notes that primates appear to have a surplus intelligence for their everyday wants of feeding and ranging, but that the social complexity inherent in many primate groups might have been a significant selective pressure for primate intelligence (Byrne & Whiten, 1997; Humphrey, 1976; Whiten & Byrne, 1988). Group living must be beneficial overall to each member, or it would not occur; however, only

individual (and kin) benefits drive evolution. For each individual primate, this sets up an environment favoring the use of social manipulation to achieve individual benefits at the expense of other group members, but without causing such disruption that the individual's membership of the group is put in jeopardy. Particularly useful to this end would be manipulations in which the losers are unaware of their loss, as in some kinds of deception, or in which there are compensatory gains, as in some kinds of cooperation. Intelligence is thereby favored as a trait. This selective pressure applies to all group members. It leads to spiraling increases in intelligence.

That the principle of agency is implicitly known or available early to infants is indicated in a variety of data. Infants are sensitive to the difference between self and externally caused motion (Leslie, 1982, 1988; Leslie & Keeble, 1987; Oakes & Cohen 1995; Premack, 1990). For example, Leslie and Keeble (1987) habituated one group of infants (causal group) to a direct launching event (one object hits another causing the hit-object to move), as in Michotte (1963). A second group (non-causal group) was habituated to a short time delay or spatial gap inserted between the impact of the first object and the movement of the second object. Accordingly, in this latter condition, there is no reason to assign causal roles to perceived objects. In post-habitation trials, the causal group experienced its reverse (film backwards). This represents both a perceptual and conceptual reversal. The non-causal group also experienced its reverse. Here, however, this represents only a perceptual reversal. If infants do not understand the perception of launching with respect to causal roles, no differences across groups would be expected in their reaction to the respective reversals. By 27 weeks, the causal group, however, produced more recovery of attention when viewing the reversal of an apparently caused event.

Infants apparently understand that only animate objects can move independently, that is, act as agents. Infants discriminate between reactive motion at a distance (an action characteristic of agents) and motion induced by direct physical contact. As indicated above, the principle of contact aids reasoning about inanimate objects; objects act on each other only if they come into physical contact (Golinkoff, Harding, Carlson, & Sexton, 1984; Leslie 1988; Oakes & Cohen 1995; Poulin-Dubois, Lepage, & Ferland, 1996). For example, 8- and 13-month-olds were habituated to novel events of a person (female stranger) or inanimate object (ball or chair) moving without any forces action on them (Poulin-Dubois & Shultz, 1988). Thirteen-month-olds showed significant decrease in fixation time in the person-as-agent condition but not in the ball-as-agent condition. The eight-month-olds exhibited the opposite pattern. In a follow-up study using unfamiliar objects, 9- and 12-month-olds were shown a stationary unfamiliar object followed by the same object moving around the room without any impetus. The unfamiliar object was a self-propelled robot with some human-like facial features. A female stranger was presented in the same way. The self-propelled robot was considered incongruous by infants of both ages as indicated in an increase in their negative affect.

The contact principle appears to be suspended by infants in reasoning about human action (Spelke, Philips, & Woodward, 1995). Seven-month-olds were habituated to objects or people disappearing at one end of screen, while a second object or person appeared at the other end. In post-habituation trials, with the occluder removed, one of the objects or people is shown moving toward the other, who starts to move after either a collision or no collision. In the inanimate object condition, the majority of infants looked longer at the test films that did not show a collision. They did not show this tendency in the person

condition. Hence by 7 months infants assume inanimate objects require contact to cause the other to move whereas people do not.

Infants are also sensitive to goal-directed, as opposed to random, action by the end of their first year. From about 3 months, infants discriminate animate-biological motions versus random or mechanical ones (Bertenthal, 1993). Moreover, by 3 months of age, infants are sensitive to information specifying social contingencies and agent intentionality (Rochat, Morgan, & Carpenter, 1997). To show this, 3- and 6-month-olds' visual preferences for 2 different dynamic events were compared. One event showed a pair of discs moving around a screen independently. The second showed a "chase" event, in which the same pair of objects is displayed in a systematic interaction of chasing (an intentional social event). Three-month-olds prefer the chase event. Infant sensitivity to intentional events was demonstrated also by Gergely, Nadasdy, Csibra, & Biro (1995). These authors habituated 12-month-olds to the event that adults interpret as goal-directed. A small computer-animated circle/ball repeatedly approached a large circle by jumping over a rectangular figure separating them. This event is interpretable as the rational action of avoiding an obstacle to reach a goal. In post-habituation trials, the obstacle was removed. Infants saw either of two events. An "indirect" event made-up of the old/familiar (now non-rational) jumping action, which is not justified in the current context. A new, rational action, a "direct" event, which showed a small circle moving directly toward a large circle. Infants looked longer at the indirect test event, indicating they had perceived the moving ball as intentional. They expected it to go directly for its object (the second ball). This discrimination ability shows up between 6 and 9 months (Csibra, Gergely, Biro, Koos, & Brockbank, 1999).

Infants also perceive goal-directed action in reaching behavior. Woodward (1998) found 6- and 9-month-olds sensitive to the goal-related, in contrast to spatio-temporal, properties, of a reach act. She habituated infants to the sight of a hand reaching to and grasping 1 of 2 toys. In one test event, "new object-old path," the arm-hand reached to the old location and grasped a different object. In a second test event, "old object-new path," the arm-hand grasped the same object, but in a new location. If infants simply perceived the habituation event in terms of the arm's spatial movement, then the "new object-old path" would seem familiar. However, if they perceived the habituation movement as an arm grasping a particular target object, then the "old object-new path" would be familiar. Babies looked longer when the actor grasped a new toy than when she moved through a new path.

Infants, moreover, consider the human hand as an agent of functional actions (Leslie, 1984). Infants were habituated to a hand picking up a doll. In posthabituation trials, infants were tested on a sequence showing a hand picking up a doll again, but with a small gap between the hand and object. Seven-month-olds recover attention to this change. They do not to a similar change, when there was no hand but only another object making the same movements.

An early understanding of agency is indicated in children's language use as well. Use of the agentive case, which expresses the notion of an animate being initiating some action, is pervasive in children just starting to use language (Bloom, Lightbown, & Hood, 1975; Bowerman, 1976). By 18 months, infants typically attend to the agent in an observed agent-action-recipient sequence both during and after the action (Robertson & Suci, 1980). Moreover, syntactically, young children consistently place agents before the verb (Bloom et al., 1975; Bowerman, 1976; Chap. 11, this volume).

Mental States

The principle of mental states concerns the relation between persons, their internal states, and behavior. It specifies that persons are not understood on the plane of action alone, but that mental states underlie and determine their actions. Mental states include emotional states.

Social interaction relies on an understanding of one's own and other's mental states. This is all the more true to the extent that social interaction is novel and unpredictable. Indeed, the existence of predictable behavior mitigates against the need to know and talk about others' mental states (Vinden & Astington, 2000). Hence awareness that mental states underlie behavior may originate in social interaction to the extent that such interaction is unpredictable.

That the behavior of persons is mediated by mental states appears to be understood very early in life. Infants show an understanding of persons as intentional agents. For instance, infants' imitative acts are often focused on objects and represent first evidence of shared meaning between peers (Mueller & Silverman, 1989). Moreover, even babies as young as 6 months expect people's actions to be related to objects in ways that are continuous with more mature, intentional understandings (Legerstee et al., 2000). In experimental conditions, infants were habituated to an actor who either talked with or reached for and swiped something hidden behind an occluder. In the test events, the actor was occluded, but the infants were shown either a person or an object. Infants who had been habituated to the talking actor looked longer at the object, whereas infants who had been habituated to the actor who reached and swiped looked longer at the person. Hence, infants associated communicative acts with people and manipulative acts with objects.

In early interactions, infants engage in behaviors, such as teasing, that require an understanding of the mental states of others (Reddy, 1991). Between 8 and 14 months, social interaction seems infused with mental state understanding. Trevarthen and Hubley (1978) describe secondary intersubjectivity in interpersonal interaction. Intentional communication emerges (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). Such social tool use is seen in deictic gestures, such as pointing, to request adult help in getting an object. Indeed, pointing to reference objects, accompanied by gaze alternation, indicates that children expect adults to behave autonomously after seeing such signals (Murphy & Messer, 1977). Adamson and Bakeman (1985) document triadic awareness, joint reference and affect being expressed in these periods of shared object play. Joint visual attention (i.e., understanding others' gazes) also develops during this time (Butterworth, 1991; Scaife & Bruner, 1975). Indeed, 12- to 18-month-olds can use information about focus of attention to disambiguate the referent of another's emotional message when at least two potential referents are available (Baldwin & Moses, 1994, 1996). Finally, social referencing indicates understanding of mental states in self and others (Feinman, 1982; Sorce, Emde, Campos, & Klinnert, 1985).

At about 17 months infants begin to turn toward other people to request help in recreating an interesting event (Sexton, 1983) and begin to restrict their communicative overtures to people (Bates, Camaioni, & Volterra, 1975). From about 18 months to 2 years of age, children's understanding of intentional states is manifest in symbolic behaviors. They engage in pretense (Leslie, 1987). Further, word learning during this time is based on the intentional states of the child (Bloom, 1993) and on the child's discernment of the intentional states of the

adult (in terms of referential intent with respect to an object-focus; Baldwin, 1993, 1995; Tomasello & Barton, 1994; Tomasello, Strosberg, & Akhtar, 1996). Moreover, words for mental states begin to appear in children's vocabulary (Bretherton, McNew, & Beeghly-Smith, 1981; Wellman & Bartsch, 1994). Additionally, in child language, agents appear as experiencers of mental states (Bruner & Lucariello, 1989).

In addition, toddlers can reason about desire. For example, 18-month-olds understand desires as subjective as shown by demonstrations that they know you might want broccoli, as compared to their own preference for crackers (Repacholi & Gopnik, 1997). Two-year-olds can predict actions and reactions related to simple desires and they pass desire reasoning tasks (Wellman & Woolley, 1990). In addition, they show cognitive-perspective taking ability and the ability to understand others' feelings (Denham, 1986). Moreover, preschoolers show an understanding of the nature of mental states or entities, for example, that thoughts are nonmaterial, subjective, or mental things in contrast with substantial, objective, physical objects (Wellman, Hollander, & Schult, 1996).

Emotional Evaluation

The principle of emotional evaluation concerns the presumptive outcome for contingent, agency-directed social interaction. It specifies that contingent, goal-directed social interaction succeeds. Hence, the default or unmarked emotional assessment or interpretation of such interaction is neutral to positive.

The primacy of neutral-positive emotional interpretation or assessment is evident in a variety of data. Early mother-infant interaction is disrupted and is less positive and more negative arousal is caused in infants by maternal depression (Cohn & Tronick, 1983; Cohn, Campbell, Matias, & Hopkins, 1990).

In ontogenetic development, positive emotion affords development. When the two expressive systems of affect (already in place) and language/word learning (being acquired) are first integrated, this integration is restricted to positive affect. Words, when first said with emotion, are said with positive emotion only (Bloom, 1993). Similarly, simpler narrative structures are associated with positive experiences, while negative emotional experiences lead to more complicated narrative structure (Dunn, 1999). This suggests again that positive affect undergirds the integration of the expressive systems of language (here in terms of base narrative structure) and affect.

Positive or emotionally gratifying evaluation or assessment appears to be the default condition of normative cognitive processing in healthy subjects. For example, when memories are reconstructed, they are shifted in emotionally gratifying and self-enhancing directions (Bahrick, Hall, & Berger, 1996; Greenwald, 1980). Bahrick et al. (1996) showed college students to make errors that inflate their grades, when remembering their high school grades. Further, people remember their choices in an emotionally gratifying way (Mather & Johnson, 2000; Mather, Shafir, & Johnson, 2000).

Reciprocally, nondepressed individuals at high cognitive risk for depression process information about themselves more negatively than do those with positive cognitive styles (Alloy, Abramson, Murray, Whitehouse, & Hogan (1997). This preferential processing of self-referent negative depression-relevant information is revealed in greater endorsement, faster processing, greater accessibility, and better recall of content involving themes of incompetence, worthlessness, and low motivation. These high cognitive risk participants also are less likely to process positive depression-relevant stimuli than are low cognitive risk participants. Of course, such

negatively toned self-relevant information processing is characteristic of depressed individuals as well (Segal, 1988).

Fittingness

Finally, there is the fittingness principle. This principle concerns the relation among the other four principles. It binds these together. The fittingness principle states that the normative relation for the operation of these principles is that of synchrony. Specifically, agents in given social interactive exchanges perform actions that are pursuant to their goals and persons/identities. These goal-directed actions achieve the goal (intended outcome). Agents and their interactants engage in contingent interaction, fulfilling and complementing roles. This presumes mutual understanding of one another's mental states.

Learning Paths in the Sociality Domain

Learning related to the sociality domain consists in acquisition of those knowledge structures that we use to participate in and understand social interaction. Three to-be-learned structures will be treated in this section. Two of these are event knowledge structures: *scripts* and *counterscripts*. The third is the *intentionalist causal framework* (*folk psychology*).

These three are chosen to illustrate three developmental levels of learning. Scripts represent domain-based early learning. Acquisition of the intentionalist causal framework represents domain-based later learning that is core-consistent knowledge extension. The to-be-acquired knowledge accords with core domain knowledge and represents an extension of such. Counterscript learning is illustrative of domain-related (but not based) later learning that is core-inconsistent knowledge acquisition. The to-be-acquired knowledge is inconsistent with or contradicts the skeletal, core knowledge in the domain.

Domain-Based Early Learning

To be a competent, full-fledged member of the culture, we must understand, participate in, and even predict social interactive events. Hence, we must acquire knowledge of the many kinds of sociocultural events that we experience. Scripts are our knowledge or representations for expected, commonplace, sociocultural activities. These include caretaking activities (e.g., getting dressed; meal-times) and other activities, such as going to school, restaurants, stores, and the doctor's office. Also considered to be script events are ritualized occasions, such as birthdays and holidays.

Defining sociocultural events and understanding how they are learned requires an analysis of their structure. Four aspects of event structure are discerned: causal relations, emotive structure, person and interpersonal relations, and temporal-spatial relations. Each event structure we learn (with scripts and counterscripts considered in this chapter), can be analyzed in terms of its degree of consistency with the principles organizing the sociality domain.

Script-event structure, with respect to its instantiation of the four aspects of event structure, is consistent with the five skeletal principles representing initial knowledge in the sociality domain (see Table 10.2).

In script representations, causal relations are based in an agent who undertakes appropriate, goal-directed actions that achieve the goal. An essential feature of script knowledge is that causal relations are successful (see also Trabasso & Stein, 1996, and Trabasso, van den Broek, & Suh, 1989, for a related analysis of events in terms of their causal relations). Hence, the agency principle is honored in script events. The result is that script events embrace a neutral to positive/happy emotive structure. This in turn is consistent with the emotional evaluation principle.

Further, in script structure, interpersonal role relations are contingent and reciprocal. For example, the diner orders the food, the waitress takes the order and brings the food, and the diner then eats the food. At birthday parties, the guests bring the gifts; the birthday honoree receives them. Hence, the contingency principle also is honored. The smooth coordination of script role relations is strong indication that participants are cognizant of one another's mental states. Additionally, relative to temporal-spatial relations, script events occur in discrete or delimited time-place contexts. They occur, for example, at McDonald's, at school, at the grocery store, at the birthday party. Finally, scripts embody the fittingness principle. The principles of agency, contingency, mental states, and emotion evaluation operate in synchrony in script events.

As noted, on an epigenetic view of learning and cognitive development, learning is a function of the degree to which existing mental structures overlap with the structure of the input. Assimilation of inputs is more likely where a structure map exists between what is to be learned and what is already known. The structure of script events is consonant with the initial skeletal principles in the sociality domain. Accordingly, script learning occurs through structure mapping. This leads to two predictions. One is that script learning should be early, easy, and non-dependent on instruction. Second, script learning should be universal.

With respect to the timing and ease of learning, it is now well documented that scripts can be acquired by very young children. Learning begins as early as the second year, and scripts become a predominant knowledge structure for children (Bauer & Mandler, 1990, 1992; Bauer, Wenner, Dropik, Wewerka, 2000; K. Nelson, 1986; K. Nelson & Gruendel, 1981; Ratner, Smith,

& Dion, 1986). Children amass a substantial knowledge base of commonplace events. These include activities such as caretaking, conventional organizational structures, such as school, restaurants, stores, and ritualized occasions such as birthdays and holidays.

That script knowledge is robust in young children is evident also in the cognitive competencies afforded by scripts. Scripts lead to the development of taxonomic categorization through a script-based categorical organization known as the slot-filler category (Lucariello, 1998; Lucariello, Kyratzis, & Nelson, 1992; Lucariello & Nelson, 1985). Slot-filler categories represent the items that fill the slot created by a script-based action. Symbolic behaviors of language and play are also supported by script knowledge (Lucariello, 1987; Lucariello, 1990; Lucariello, Kyratzis, & Engel, 1986; Lucariello & Nelson, 1987). Moreover, scripts support inferential reasoning (Hudson & Slackman, 1990), the understanding of temporal (Carni & French, 1984) and causal (French, 1988), relations planning (Hudson & Fivush, 1991; Hudson, Shapiro, & Sosa, 1995; Hudson, Sosa, & Shapiro, 1997), self-understanding (K. Nelson, 1997, 2000), and autobiographical memory (Fivush, Hudson, & Nelson, 1984; Hudson, Fivush, & Kuebli, 1992).

Since script knowledge is consistent with initial domain knowledge, scripts are presumed to be universal. Although little empirical work has been conducted to examine this point, some data can be relied on. For example, the script-based slot-filler categories documented by Lucariello and colleagues (Lucariello & Nelson, 1985; Lucariello et al., 1992) in young children's knowledge bases have been documented in other cultures (Nelson & Nelson, 1990; Yu & Nelson, 1993). This provides indirect evidence that script knowledge is universal. Moreover, several studies show culture-

specific script effects on information processing. Americans better summarize and recall stories when these fit their own cultural scripts (Forgas & Bond, 1985; Kintsch & Greene, 1978), and they misremember stories based on foreign scripts as being more like stories based on American scripts (Harris, Lee, Hensley, & Schoen, 1988). More strikingly, distinct cultural groups interpret the same event, such as a wedding or a game or a fight, differently based on their own cultural script knowledge (Carrell, 1983; Reynolds, Taylor, Steffensen, Shirey, & Anderson, 1982; Steffensen, Joag-dev, & Anderson, 1979).

Hence, the data reveal domain-based early learning to consist in script acquisition. They show script learning to be early, easy, non-reliant on instruction, and likely universal.

Later Learning: Core-Consistent Knowledge Extension

An *intentionalist causal framework* entails the explanation and prediction of behavior by appeal to internal, mental (including emotional) states. It involves interpreting behavior through psychological causes. This framework is very similar, if not identical to, what is meant by "folk psychology."

For the past decade, considerable attention has been paid to one behavior emblematic of the intentionalist causal framework: *false belief*. False belief refers to one's understanding that another has a false belief—an incorrect or erroneous belief with respect to reality. Accordingly, false belief provides evidence for mental state understanding (i.e., understanding the distinction between mind (internal mental states) and real-world events and situations).

False belief is commonly assessed through one of three kinds of tasks. In a "surprising contents" task, the child is presented with a familiar object (e.g., crayon box) and states what it normally contains (crayons). Then the

child discovers the object to hold other things instead (e.g., candies). The child is then asked what someone else, who hasn't looked inside, will think is in the object (e.g., crayon box). False belief is indicated by an answer stipulating the normal contents (e.g., crayons). The "surprising identity" task relies on a deceptive object to engender a false belief. For example, in the rock-sponge task, the child sees, without touching, a sponge painted to look like a rock. The child presumably believes it to be a rock. Then the child handles the object. The child is then asked what it is and answers "sponge." The object is then placed back in its original location. In the test of false belief, the child is asked what another child, who will only see the object, will think it is. The answer "rock" gives evidence of false belief. The third task entails "change in location," and the Maxi task is most commonly relied on here. The child is presented with a scenario in which Maxi puts his chocolate in the kitchen cupboard and leaves the room to play. While he is away (and cannot see), his mother moves the chocolate from the cupboard to a drawer. Maxi returns. The false belief question has been asked in terms of action (where will Maxi look for his chocolate), thoughts (where does Maxi think his chocolate is), and language (where will Maxi say his chocolate is).

Clearly then, false belief is grounded in the intentionalist causal framework, just the ability to explain the behavior of self and others by appeal to mental states. Acquisition of this framework represents domain-based later learning of the "core-consistent knowledge extension" variety. The intentionalist causal framework is consistent with initial, skeletal knowledge in the sociality domain. The principles of contingency, agency, mental states, emotional evaluation, and fittingness are recruited in this framework. Accordingly, these principles afford assimilation of the relevant inputs, making structure mapping operative in acquisition.

Yet, the intentionalist causal framework requires a more enriched and a more controlled understanding of these principles than is inherent in their skeletal form. It requires that these principles be re-represented conceptually. The outcome is the development of the *concepts* of belief and false belief, for example. Reliance on the intentionalist causal framework to explain and predict behavior requires, in addition, a metacognitive understanding of these principles as well. Put differently, folk psychology entails being *meta-social*. Indeed, tasks such as false belief force a meta-use of these principles. To capture the more conceptual and more meta-understanding of these principles entailed in the intentionalist causal framework, we return to the notation system used earlier in this chapter. It can be said that, in the intentionalist causal framework, these principles are operative *in capital letters* (e.g., agency with a capital "A"). The difference in knowledge of these principles across their skeletal and "conceptual plus meta" form is analogous to the difference in knowledge of counting across the nonverbal and verbal counting principles.

Because conceptual and meta-knowledge, not simply skeletal knowledge, of these domain principles is required in the intentionalist causal framework, structure mapping alone will not be sufficient for its learning. These principles will need to be exercised, practiced, mined, honed. One's culture has to provide multiple, indeed ubiquitous, examples of the framework. In this way, culture can be said to amplify cognitive development (Greenfield & Bruner, 1966). Many, but not all, cultures provide such data, particularly those of agency and mental states, leading to their conceptual and meta-development.

Two predictions follow from this discussion of how the intentionalist causal framework is learned. One is developmental. Because learning is based on more than structure mapping alone, learning will occur

later, ontogenetically, than knowledge acquisitions based only on structure mapping. Accordingly, learning of the causal intentionalist causal framework should be later and more effortful than script learning. The latter occurs on the basis of structure mapping. The second prediction is that this learning is unlikely to be universal. Since learning depends also on recruiting the multiple lines of evidence in the sociocultural environment, and these environments are not the same everywhere, it is not expected that the intentionalist causal framework would be a universal acquisition. The data on the acquisition of false belief bear out both these predictions.

With respect to development, all indications are that learning the intentionalist framework is a case of later learning. Scripts are learned beginning in the second year and are well established by age three. This, however, is the modal age at which learning of the intentionalist causal framework is just beginning. False belief tasks are generally failed by the 3-year-old and are not passed until the child is between 4 and 5 years of age (Gopnik & Astington, 1988). A recent meta-analysis of 178 separate studies indicates that false belief develops between the ages of 3 and 5 years (Wellman, Cross, & Watson, 2001). The method of assessment (i.e., the three kinds of tasks) does not affect this pattern.

Other data support the view that a folk psychology begins to be established around 3 years of age. Understanding of mental states—in terms of distinguishing intentional acts and outcomes from accidents, mistakes, and passive movements—does not appear before about 3 years of age (T. Shultz, 1980; T. Shultz, Wells, & Sarda, 1980). Additionally, Lucariello (1990) explored the kindergarten-aged children's abilities to explain behavior through an intentionalist causal framework. Even at this age, children generally did not invoke psychological causes for behavior. Indeed, such invocations seemed to

require a trigger, consisting in the presentation of incongruous behavior. Other data similarly show that psychological explanations of human actions and emotional reactions, where such are explained in terms of actors' mental states, are not apparent prior to age 3 years (Bartsch & Wellman, 1989; Lillard & Flavell, 1990; Schult & Wellman, 1997; Wellman & Banerjee, 1991).

Interestingly, Wellman et al.'s (2001) meta-analysis of theory of mind development uncovered four task variables that independently contribute to (i.e., enhance) children's performance. Three of these are consistent with the initial principles in the sociality domain, which is likely why they emerged as relevant. Indeed, the present account of initial knowledge in the sociality domain provides an explanation for these findings on the effects of task variables. These findings are left unexplained by Wellman et al. (2001).

One variable, motive, refers to a task variation in which a deceptive motive is explicitly stated for a change of location or unexpected contents (e.g., the chocolate was moved to trick the protagonist Maxi). This manipulation accords with—in fact, exploits—the agency principle. A second variable, salience of the protagonist's mental state, refers to manipulations in which the protagonist's belief is clearly stated or pictured (e.g., "Maxi thinks his chocolate is in the cupboard/drawer," and the false belief question, "Where will Maxi look for his chocolate/think that it is?"). This manipulation is consistent with and indeed relies on the mental states principle. The third variable, participation, refers to the child's setting up or manipulating the initial task situation. In some cases, it refers also to the child's performing the essential transformation (e.g., moving Maxi's chocolate; substituting the candies for the crayons in the crayon box). That the child's participation in the social situation of the experimental task improves task performance would be predicted

from our claim that humans are prone to sociality. Moreover, in participating, the child's social interaction is following many of the initial principles of the domain: contingency, agency, and mental states.

As noted, learning the intentionalist causal framework was thought to be a non-universal acquisition. Here again the data support the prediction. Children from the Peruvian Andes who speak Quechua (a language with no separate lexical items for many mental states) found questions about mental states very difficult and did poorly on false belief (and representational change) tasks (Vinden, 1966). More recently, Vinden (1999) studied, in Africa and New Guinea, three different indigenous groups. Also studied were three groups of Western children (North American, Australian, and European). In this method, children were involved in creating a false belief in another person. Moreover, in assessment, there was a component concerning the prediction of emotion in the other. Two of the three indigenous groups showed a delay of several years in mental state understanding (understanding that people will act on the basis of what they believe, rather than merely reacting to the way the world is). However, one of these groups—Tainae of Papua, New Guinea—found the direct question about the other's thoughts much more difficult than the question about where the other would look. This was true even in children as old as 15 years of age who did not perform above chance on the direct question about another's thoughts. On other tasks, only the oldest children performed above chance on false belief (and representational change) questions using their word for "think."

With regard to the ability of predicting an emotion based on false belief, the English-speaking children appeared to follow the usual path from a situation-desire to belief-desire understanding of emotion. Almost all children from the three indigenous groups had

difficulty predicting an emotion based on a false belief about the world. Hence, the non-western children did not show a clear progression toward a mentalistic understanding of emotion.

In thinking about sources of data in Western culture that are both salient and that seem particularly related to learning the intentionalist causal framework, three seem very relevant. These are: "intentionalist" model of language socialization, self-reflective schooling practices, and an "independent" self-concept.

The intentionality model of language socialization is typical of Western middle-class culture (see Snow, 1986). It reflects the skeletal principles of agency and mental states and hence can lead to conceptual and meta-knowledge of them. Herein the child is seen as an intentional agent, with mental states, from the outset of life. Children are treated as intentional communicative partners, and speech is directed *to* them from infancy. Moreover, characteristics of child-directed speech, such as expansions and requests for clarification, focus on the child's intentional states. Further, much of parent-child conversation, such as teasing, joking, and joint pretense, is relevant to mental states (Cutting & Dunn, 1999; Dunn, 1999; Dunn & Brown, 1993). Dunn (1999) describes parental attributions of intentionality to child behavior as typical in the second year. Moreover, she finds four kinds of interaction to be common in the third and fourth years. These kinds—mindreading, joint pretending, early narratives, and early deception—are thought to assist theory of mind learning.

Schooling experiences as well can reflect and exercise the skeletal principles of agency and mental states. Such can lead to conceptual and metaknowledge of these principles. Discourse practices are a particularly important feature of Western schooling in this regard. These include practices

in which pupils are routinely asked to explain and justify their thinking and answers (Scribner & Cole, 1981). In cross-cultural research examining effects of literacy practices and schooling on cognition, the most pervasive schooling effect was on the ability to explain one's cognitive performance (Scribner & Cole, 1981). Naturally, this entails thinking about one's own mental states and knowledge. These discourse practices also include the related practice of teacher test questions (questions for which the teacher already knows the answer; Brice Heath, 1983). Test questions focus on the child's mental states and knowledge and would presumably foster conceptual and metaknowledge about mental states.

Finally, regarding self-concept, the independent self-concept, which is emphasized in some cultures, recruits the principles of agency and mental states. Such would foster conceptual knowledge and meta-use of each. Relevant effects on cognition of an independent self-concept have been found (Greenfield & Bruner, 1966; Markus & Kitayama, 1991; Vinden & Astington, 2000). For example, Greenfield and Bruner (1966) found self-consciousness to result from the independent value orientation. Self-consciousness is a facility in reasoning about mental states. Indeed, self-consciousness was lacking in their Wolof subjects in Senegal. In their conservation studies, Greenfield and Bruner were unable to use the traditional subjective form of justification questions (e.g., Why do you think there is more water in this glass than in that glass?). These subjects had difficulty with this type of question. It was necessary to transform the question to an objective form (e.g., Why is there more water in this glass than in that one?). More recently, an independent self-concept was found to facilitate such cognitive activity as hypothetical and counter-factual reasoning (Markus & Kitayama, 1991). These forms of thinking demand complex reasoning about mental states.

Later Learning: Core-Inconsistent Knowledge Acquisition

To be full-fledged participants in our culture, we must have some structured understanding about unexpected events. Script event structures cannot be the only ones acquired. Counterscripts constitute an important class of event structures (Lucariello, 1994; Lucariello & Mindolovich, 1995, in press). These structures capture much of our understanding of the irregularity of events as well as how to "play" with the irregularities. Classic among counterscript representations are those for situationally ironic events (Lucariello, 1994; Lucariello & Mindolovich, 1995, in press).

An analysis of counterscript events in terms of elements of event structure shows these events to violate the initial, skeletal principles in the core domain of sociality. In particular, the principles of agency, emotional evaluation, and fittingness are violated. Four of the most prototypical counterscript ironic event kinds will be treated here. Three of these—"Wins," "Losses," and "Double Outcome"—exhibit aberrancy in causal relations. In contrast to script events, the successful and straightforward links among agency, goal-directed action, and outcome do not hold. The aberrancies in causal relations show a failure of the agency principle in that the goal-directed action of an agent is rendered impotent. In this, except for Wins events, the emotional evaluation principle is also violated. The default emotional assessment of neutral-positive cannot hold.

Wins counterscript events are the most similar to script-event structure. A major type of Win is Fluke-Win. In these events, inadvertent, non-goal-directed actions, rather than goal-directed ones, secure the outcome. Such is the aberrancy in causal relations. Nonetheless, the intended goal is achieved in the outcome making these events very similar to script events. Moreover, because the desired

outcome is attained, the emotive structure of Fluke-Win counterscript events is, like that of scripted events, positive/happy.

Losses and Double Outcomes also exhibit aberrant causal relations. These relations, however, lead to loss outcomes and hence to script-contradictory negative/sad emotive structure. Loss events entail a single loss outcome. Planned-Loss ironic events refer to backfired plans. The agent has a goal and takes appropriate actions. Rather than securing the intended outcome, as in script causal relations, these actions achieve the outcome opposite to that intended. The result is that the loss outcome is also self-inflicted.

Double Outcome ironic events entail two opposing outcomes, win and loss. In Fruitless Win-Double Outcome events, the agent has a goal and takes appropriate actions, but the outcome is lost (not achieved). Subsequently, when the outcome is no longer relevant or desired, it actually becomes attainable. This final outcome constitutes a bittersweet experience. It represents a loss because it arrived too late, but it reminds one of the win that it could have been.

A different variety of counterscript ironic events also violate the initial skeletal principles of the sociality domain, in particular the agency and fittingness principles. In these events, however, this is accomplished through aberrancy, not in the causal relations, but in the temporal-spatial relations in conjunction with person-interpersonal relations. Imbalance counter-script ironics capture contradiction in person relations, such as agent-action or agent-goal, across contexts. In Temporal-Imbalance, person relations are contradicted across distinct temporal contexts, generally past versus present (e.g., the clumsy classmate who becomes the prima ballerina; the inmate who later becomes a lawyer). Apparent here is a weakened or diluted sense of agency. The agent is not steady or constant.

Counterscript ironic events may be distinguished from other unexpected, script-aberrant events that do not qualify as counterscript events. These nonscript events exhibit idiosyncratic anomalies. Hence, they show no common instantiation of the four aspects of event structure. For example, in a deviation of the Planned-Loss example (Table 10.2), let us say that while Billy is putting away his telescope for safekeeping, he does not drop it. Rather, he has to run back to his party because his friends are fighting. In this case, an anomalous, nonscript event has occurred. However, a counterscript ironic event has not. Presumably, we do not acquire general, semantic representations for these events. They are not learned.

How are counterscript events learned? Several learning tools will be needed. As noted, because counter-script event structure violates the initial skeletal principles of the sociality domain, structure mapping will not play much of a role in learning. To the extent that it operates at all, it would pertain to the Wins event kind, which represents the greatest structural match, among all counterscript ironic kinds, with script events.

Accordingly, for the most part, counterscript learning occurs in the absence of potential structural maps. Indeed, a new structure has to be mounted. Moreover, prior script knowledge has to be overcome in learning because its inconsistency with the relevant inputs renders it a barrier to new learning. In scripts, one's clumsy classmate becomes a clumsy waitress; in counterscripts, one's clumsy classmate arrives at a contradictory state of prima ballerina. In scripts, one's plans work out; in counterscripts, plans backfire. Prior script knowledge is also a barrier to learning in the apparent tendency to resist changing the knowledge base. Data are simply assimilated to the existing structure. Indeed, learners often fail to realize that they do not understand a new concept. Due to

these conditions, counterscript learning will be effortful and protracted. In addition, it will require learning tools other than structure mapping.

Of the learning tools described earlier, some are particularly important for counterscript learning. These include pattern analysis, frequency computing, and metacognition.

Learning counterscript event structures relies on pattern matching. All event inputs—typical and atypical—must be compared against script structure to determine matches and nonmatches. Moreover, among the mismatches (the input of atypical events), the child must detect the event structure (e.g., causal relations as well as temporal-spatial and person-relation patterns) that distinguishes counterscript ironic events from other unexpected (nonscript) events that exhibit idiosyncratic anomalies. These latter events show no common instantiation of event structure. Recall the example cited earlier of the fight suddenly breaking out at Billy's birthday party. Representations for these latter events must not be learned as if they were counterscript ironic structures, and perhaps not learned at all. Hence, the child must make such distinctions among atypical events.

This process is made more complicated by prior knowledge. Prior knowledge can impede interpretation of the input. Because the child's knowledge about doing daily things is contradicted in the experience of counterscript ironic events, the input of counterscript atypical events contradicts available mental structures. Experiencing inputs contradictory to prior domain knowledge can prevent the learner from moving onto the appropriate learning path. Or it can cause misconceptions in learning, based on misinterpretation of or failure to distinguish among inputs (Hartnett & Gelman, 1998). Learning problems such as ignoring input or wrongly assimilating it into existing structure are possible (R. Gelman, 1991; R. Gelman & Williams, 1998).

Additional learning tools can help the child distinguish among atypical events. One is contingent frequency computing. Presumably, the counterscript patterns occur more frequently than do idiosyncratic ones. This gives learners an opportunity to keep track of cases that eventually can be organized.

Learning is also facilitated by the ability discussed earlier to create and use re-representations, including spoken and written language. Counterscript ironic patterns, in contrast to anomalous, idiosyncratic unexpected events, are more likely to be re-represented culturally. Counterscript ironic events are often, if not always, labeled as such when referenced (e.g., the newscaster who heads a story, "Ironically..."). Moreover, ironic events are commonly rendered in texts, such as children's books (Dyer, Shatz, & Wellman, 2000). The re-representation serves to increase the salience of counterscript patterns among the input of atypical events. Put differently, children are offered ubiquitous and redundant examples of inputs relevant for acquiring these new event structures.

Because learning counterscript event structures entails acquiring a second tier of event knowledge contradictory to the first, advanced metacognitive skills will also be needed. They are advanced in that their operation is dependent on, though not automatically precipitated by, the learner already having some related knowledge (script knowledge).

One metacognitive skill required for counter-script learning may be defined as a *skeptical frame of mind*. This frame consists in a critical stance or detachment toward one's knowledge, on which knowledge is not viewed as fact, but is subject to question. On this frame, one's knowledge structures or categories are understood as limited—insufficient and inaccurate in accounting for all the relevant inputs (see Goffman, 1974, for discussion of frames of mind). This orientation to one's knowledge enables the learner to

overcome the constraints of prior knowledge to acquire and process structures inconsistent with or contradictory to related prior knowledge. In counterscript learning, the learner must transcend prior, related script knowledge because the new knowledge contradicts the prior knowledge. If children stick with their primary base of event structures, even in the face of contradictory input, learning will not occur. Rigid adherence to one's current categories of knowledge can prevent learning.

A second metacognitive skill needed is *dialectical metarepresentation*. This is reasoning about contradictions in one's own thought and relative to metarepresentations. In learning counterscripts, contradictory (not simply inconsistent) tiers of event knowledge must be maintained in the knowledge base. These tiers are the primary representations, scripts, and the secondary or metarepresentations, counterscripts. Although scripts are transcended in learning counterscripts, scripts must also be maintained during and after acquisition of counterscripts. Scripts, although inadequate in accounting for all event inputs, nonetheless account for a significant share of event inputs. Accordingly, in acquiring and processing counterscript representations ("not A"), which render how events are "not supposed" to occur, one must necessarily understand script representations ("A"), which specify how they are "supposed" to occur. Dialectical metarepresentation is required for managing such contradictory tiers of event knowledge.

The very challenging nature of learning counter-scripts, due to their being about core-inconsistent knowledge acquisition, leads to two predictions about their acquisition. It is likely to be protracted and effortful, hence a relatively late-accomplishment. Moreover, this learning is likely non-universal.

To date, two studies have examined children's counter-script learning and they reveal it to be late-emerging and difficult

(Lucariello & Mindolovich, 1995; Lucariello, Mindolovich, & Le Donne, 2001). In a story completion task, 6- and 8-year-olds were presented with story stems and asked them to complete the stories (Lucariello & Mindolovich, 1995). Endings were analyzed for counterscript ironic status (Lucariello & Mindolovich, 1995). Results showed that even at 8 years of age children do not easily produce counterscript ironic events. Half of these children never did so. These data reveal the effortful nature of counter-script acquisition. Moreover, they point to the role of metacognition, in terms of a skeptical frame of mind, in counterscript learning. Children at both ages spontaneously preferred to end their stories as scripts (i.e., with endings that meet the agent's goal or that add an appropriate action in the event sequence). Counterscript production generally occurred after an intervention from the experimenter requesting a "sad" ending. These data illustrate the tendency to stick with one's prior knowledge/categories in learning. They underscore the necessity of developing a skeptical frame of mind.

In a follow-up study, child counterscript learning was assessed through a comprehension methodology using a story recall task (Lucariello et al., 2001). Kindergarten and third grade children's recall of script, counter-script ironic, and anomalous (idiosyncratic) unexpected event stories was studied. With respect to counterscripts, learning of the four structures already described was assessed. These were: Fluke-Win, Planned-Loss, Fruitless Win-Double Outcome, and Temporal-Imbalance. The premise of this methodology is that better recall is elicited by stimuli that tap underlying knowledge structures. Accordingly, completed counterscript learning would be evident in a recall pattern wherein script and counterscript stories are well recalled and comparably so, while anomaly stories are less well recalled. Script and

counterscript events are to be learned and hence stories about these events should tap underlying knowledge structures. In contrast, anomaly events are not to be learned; hence we should not have knowledge structures for these events. Thus, stories depicting these events should not be well recalled. Here again the data show the challenge of counterscript learning. Even older children showed only partial learning and this for only two of the four counterscript structures whose learning was assessed.

As noted, counterscript learning, as a case of later learning inconsistent with core domain knowledge, is thought to be non-universal. To our knowledge there are not yet cross-cultural studies on counterscript learning.

CONCLUSION

The demonstrated abilities of infants and young children to use abstract information and acquire abstract concepts about objects, numbers, and people are inconsistent with the long-standing view that they are preconceptual, perception-bound, and limited to concrete reasoning or stimulus-response pairings. Such findings have motivated the development of the rational-constructivist class of theories of cognitive development. Even though appeal is made to innate contributions to development, it is a mistake to conclude that this is paired with the idea that cognitive development does not involve learning. Instead, the problem of learning in development has to be restated as follows: What kind of learning theory fits the developmental facts? This was the central question addressed in this chapter—hence the focus on mental learning tools that the mind can recruit in the name of finding and gathering data that can nurture, develop, and even create mental structures. What emerges is that an account of learning in cognitive development is likely to involve

devices that seek out and create structures. This is obviously not a traditional learning theory with its commitment to the buildup of associations. In many respects it is a learning theory that is Piagetian in spirit. In the end it differs from Piaget's because of its emphasis on innate skeletal principles and domain specificity.

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