

Comparative Cognition Between Children and Animals

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How does the human mind develop over the individual's lifetime? This is the central question of the study of cognitive development. How does the human mind work in relation to other animal minds? This is the central question of comparative psychology. Developmental comparative psychology integrates the two questions. It tries to understand how the human mind works by understanding how it came about over time, both ontogenetically (in each individual's life history) and phylogenetically (over the course of evolution). To do so, it compares the cognitive capacities and processes of individuals across different developmental time points as well as across species.

When comparing humans to other species, the main focus is usually on our closest living relatives: the other primates, in particular the nonhuman great apes, such as chimpanzees. But for many questions, other species are of great theoretical interest too. For example, when it comes to future planning or tool use, the species cognitively most similar to humans seem to be various bird species.

Developmental comparative research informs us, on the one hand, about deep cognitive continuities and commonalities of human and other minds. Such commonalities can refer to homologous cognitive faculties, which share both function and evolutionary origin in the sense that they go back to the same ancestor. This is usually the case when we find shared cognitive capacities in human and nonhuman primates (such as, to take a noncognitive example, the eyes of different primate species). But commonalities can also reflect merely analog cognitive faculties, which share a function but not the same evolutionary history and the same ancestor (like the different kinds of eyes found in mammals, insects, and many other species that share a function but no common ancestor or history). Rather, these faculties have then probably emerged independently in separate evolutionary lines—in so-called convergent evolution.

At the same time, developmental comparative psychology informs us about potential discontinuities between human and other animal minds. That adult human thinking is special and very different from other forms of animal cognition is obvious. But developmental comparative psychology can help us to understand how it is that our cognition turns out to be so radically different from that of nonhuman primates despite the fact that the biological and genetic differences are ultimately not large. Humans may differ radically in their cognition from other primates, and these differences may simply be a

matter of brute biology. We have a certain capacity but other species do not. The story may be more complex, however. The hardwired and biological differences may initially not be that big. Rather, what is special and unique about human cognition may arise step by step over developmental time. And this may be a matter not so much of individual maturation and learning alone; instead, language and other social and cultural influences and tools may be crucial.

This entry gives an introduction to the newly emerging field of developmental comparative psychology. It summarizes central empirical findings concerning commonalities and differences in humans and other species in the next two sections. The most important theoretical approaches in the field are discussed in the final section.

1 Domain-General Cognitive Capacities

A standard distinction in classifying cognitive capacities is between those that apply independently of any specific content or domains, and those that refer to specific domains and contents. This section reviews comparative research in two paradigmatic forms of domain-general cognitive capacities: (1) learning and (2) goal-directed action and problem solving. Domain-specific capacities are reviewed subsequently.

Learning

Learning, in the most general and broadest sense of experience-dependent modification of mental structures, processes, or behaviors, is a multifaceted phenomenon. It ranges from basic associative learning to high-level forms of culturally and linguistically mediated training. Evolutionarily, basic forms of associative learning such as classical and operant conditioning are, of course, ancient and widespread. This section focuses on two examples of higher forms of learning: inductive and social learning.

Inductive learning is the acquisition of new general information (e.g., “(all) swans are white”) from limited observations (e.g., of some swans, all of which are white). Basic capacities for inductive learning can be observed in human prelinguistic infants—for example, in their generalized imitation: When they see someone perform an action with a certain object (e.g., wash a toy dog) and then have a choice between objects of more or less similar categories, children from age 1 generalize systematically to intuitively more similar categories (animals in the above example). Comparatively, simple forms of inductive learning can be found in nonhuman primates as well—for example, in their learning about novel tools. One particular form of inductive learning is statistical learning. In this kind of learning, one has to take into account statistical information about the distributions of objects to reach general conclusions. Traditionally, it was long assumed that such statistical thinking is a complex and late-developing capacity that requires formal training and only emerges from late childhood (Piaget & Inhelder, 1975). New research, however, has documented spectacular capacities for intuitive statistical learning in preverbal human infants who can make systematic inferences from the statistical properties of populations of objects to randomly drawn samples and vice versa. For example, when confronted with a population (A) of 100 red and 20 yellow pieces and another population (B) of 200 red and 1000 yellow pieces, infants infer that a random

sample from population A is more favorable if they prefer red over yellow (Xu & Garcia, 2008). Analogous capacities have been documented in great apes (Rakoczy et al., 2014).

Social learning in the broadest sense refers to the modification of mental structures or processes as a function of the observation of other agents. Many forms of social learning have been conceptually distinguished, ranging from automatic forms of mimicry or socially mediated stimulus enhancement to high-level forms of intentional imitation. In human ontogeny, most forms of social learning develop early in infancy. Most impressively, perhaps, even infants engage in so-called rational imitation, in which they do not simply copy superficial behavior indiscriminately but selectively imitate either efficiently or faithfully as a function of the situational and other constraints they are currently experiencing (Gergely, Bekkering, & Király, 2002). From a comparative point of view, much research documents analogous competencies in basic forms of social learning such as mimicry or social stimulus enhancement. True imitative learning, however, in which an agent understands the intentional structure of an observed action and intentionally reproduces it under this intentional description, may, from all we know so far, be a uniquely human capacity, and one that may play a major role in the emergence and maintenance of uniquely human culture (Tomasello, Carpenter, Call, Behne, & Moll, 2005).

Goal-Directed Action and Problem Solving

Goal-directed action and problem solving—that is, the capacity to flexibly adjust one’s instrumental actions in pursuit of one’s goals and to think up new means to reach given ends—have long been considered crucial hallmarks of intelligence. But when can we ascribe such flexible goal pursuit to creatures who do not, or do not yet, speak and whom we cannot ask about their plans directly? This has been a much-disputed question in developmental and comparative psychology. One proposal by Piaget (1952) that has come to be widely accepted is the following: The clearest criterion for truly voluntary, intentional, and planned behavior is that the agent differentiates means and ends, flexibly adjusting means while persistently pursuing one end (and able to use the same means in the pursuit of different ends).

Ontogenetically, human infants show signs of such flexible goal pursuit from the end of the first year of life, at the latest. From around 8 months, children engage in action sequences with clear means–ends delineation. For example, they move obstacles out of the way in order to reach a desired object, persist if they fail, vary the means, and show the corresponding emotions of frustration in case of failure and joy after success. From this time on, children begin to use tools in order to reach their instrumental goals. In subsequent years, they acquire ever more complex capacities for representing and imagining the future (“mental time travel”) and for planning ahead in systematic and creative ways (Suddendorf & Corballis, 2007).

From a comparative perspective, capacities for goal-directed planning and problem solving can be found in many other species, above all primates (homologous) and birds (analogous). Chimpanzees, for example, use many kinds of tools in insightful ways in the wild, in order to crack nuts or catch termites. And many experimental studies since Köhler’s (1926) groundbreaking work have documented sophisticated insight and problem solving in many primate species. Some species of birds even produce tools in insightful ways themselves, for example manufacturing hooks by bending strips of wire

into the requisite form. Basic forms of future-directed planning have also been shown in many primate and bird species (Raby, Alexis, Dickinson, & Clayton, 2007).

2 Cognitive Capacities in Specific Domains

Thinking About Objects

The foundation for any form of thought is a basic understanding that the world exists independently of our perception of it—in Piaget's (1954) terms, *object permanence*. From approximately 8 months of age, children evidence simple object permanence in their active search patterns. More complex variants, such as invisible displacements, emerge in the second year of life, although alternative methods—mainly looking time paradigms—demonstrate implicit object permanence at much younger ages (Baillargeon, 1987). Basic object permanence is widespread across nonhuman animals. Even the more complex forms have been shown in various species, including all great apes, some monkey species, some dogs, and some birds (Tomasello & Call, 1997).

Basic object permanence, however, is only the most rudimentary foundation of object cognition, since it is limited to aspects of space and time. Other more complex events require more complex thought. For example, Object A (e.g., a ball) is lifted from a box, shown, and replaced inside the box. Object B (e.g., a duck) is then lifted from the box and replaced inside it. How many objects are there in the box? Based on spatiotemporal information alone, one cannot tell. Since the two objects were never seen simultaneously, spatiotemporal information remains ambiguous as to whether the two encounters presented the same or different objects. What is required to resolve this ambiguity is a form of *object individuation* that includes information about the object itself—color, shape, and so on. This form of object individuation is called *sortal object individuation* since it often relies on sortal concepts (i.e., kind-concepts, such as “ball” or “duck”). While children solve spatiotemporal object individuation very early on, they only master sortal object individuation after their first birthday (Xu, 2007). Interestingly, competence in the latter correlates with language competence, in particular with the mastery of relevant sortal labels. This language dependence spawned the suspicion that animals might not individuate objects sortally, but recent evidence has shown that at least some monkeys and great apes individuate objects based on kind-concepts much in the ways 1-year-old humans do (Mendes, Rakoczy, & Call, 2008).

Intuitive Physics

Young infants already display intuitions about the interactions between physical objects, for example that objects move as single cohesive units (cohesion) through space continually (continuity) and that two objects cannot be in the same place at the same time (solidity), and they also understand basic concepts of support and gravity. Similar intuitions have been found in various animals, including all great ape species (Povinelli, 2000).

One prominent case is the perception of and reasoning about physical causality. If a ball rolls toward another ball, which then starts to move right after contact between the two, we perceive the interaction as causal: The former ball caused the latter to move.

This perception occurs early in human ontogeny (from 4–6 months onward) as well as in nonhuman primates. One obvious and prevalent application of causal understanding is the use of tools. Already at the age of 2 years, children are able to select the most effective among tools without first engaging in trial and error. Various comparative studies suggest that several primate and bird species share children's understanding of causal relations between physical objects, enabling them to select efficient tools. After their second birthday, children begin to integrate several sources of information about the causal relation between objects: co-occurrence of events, and information about the affectivity of their own actions and those of others. In this way, they acquire more general, abstract concepts of causal relations: of sources as events that cause other events and of the possibility to actively bring about sources that cause certain consequences. Whether nonhuman animals share such an abstract understanding of causality is heavily debated (Penn, Holyoak, & Povinelli, 2008).

Numerical Cognition

It seems hard to imagine that a complex understanding of numbers might emerge in the absence of language. However, several studies with infants and nonhuman animals have demonstrated rudimentary forms of numerical cognition. For example, we can assess the exact number of small amounts (up to four items) immediately, without counting. This ability is called subitizing. Human infants and many nonhuman animal species share this basic ability (Feigenson, Dehaene, & Spelke, 2004). Human children and nonhuman primates are also able to track the exact number of items across additions and subtractions of single items. Another example is our ability to discriminate large quantities approximately. Our ability to approximate the difference between two large quantities of items depends on the relative size of the two: If we are able to discriminate 40:80, we can also discriminate 50:100, 80:160, and so on. Very young human infants and many nonhuman animals (such as monkeys, birds, rats, and dolphins) share the human capacity for analog approximation of number. There is, however, no evidence for a more complex understanding of number in animals. Even the most sophisticated, symbol-trained animals, such as Ai, a female chimpanzee with the ability to use Arabic numerals up to the number 10, remains restricted to the usage of a small, finite number of symbols. Complex understanding of numbers, however, would entail insight into the infinite extension by means of "+1" operations, which is regularly achieved by human children after their 4th birthday. After Ai had laboriously acquired usage of "5," she took just as long to learn to use "6," and so on (Matsuzawa, 1985).

Spatial Cognition

All our interactions with the physical world occur in space. Effective spatial cognition is therefore of central importance in most day-to-day activities of organisms. A series of processing systems (e.g., response learning, landmark learning, path integration, place learning) are applied and combined in different ways when processing space. To structure our understanding of spatial cognition, two dichotomies have frequently been applied to categorize spatial processing outcomes:

- *Egocentric versus allocentric processing.* Egocentric processing applies a frame of reference to all spatial information that is centered in the observer's perspective. Allocentric processing applies a frame of reference to all spatial information that is not centered in the observer's perspective but relies on spatial relations between external objects or alternatively the geometry of spatial layouts.
- *Geometric processing versus feature processing.* Geometric processing relies on spatial relations between external objects or alternatively the geometry of spatial layouts. Feature processing relies on processing characteristics of the surrounding environment—such as colors, shapes, or smells—that are not primarily spatial in nature.

Response learning and path integration, for example, largely rely on egocentric spatial information while landmark learning and place learning largely rely on allocentric spatial information. Response learning and landmark learning are relatively simple in structure while the other two systems could be regarded as more complex extensions of those two primary systems. Already at the age of 6 months, children apply the two simpler systems as well as path integration and to some extent place learning, with response learning being dominant among the four. With growing experience, the two more complex systems gain in relevance across development (Newcombe & Huttenlocher, 2000).

Most comparative work in spatial cognition investigates place learning. It entails the processing of spatial information, embedded in the local environment—that is, independent of an observer's perspective (allocentric information). A simple and elegant way to investigate place learning is by disorienting agents within a structured environment and requiring them to reorient—the so-called reorientation task. In such a task, children between 18 and 24 months of age rely strongly on the geometry of the floor-surface to reorient. In symmetrical (e.g., rectangular) rooms this strategy cannot fully disambiguate since two opposing corners are geometrically identical. To disambiguate, landmark information, such as a colored wall, can be applied. Surprisingly, even when provided with such disambiguating information, children under the age of 2 years (and rats) fail to use it and continue to alternate responses across geometrically identical corners. The same mistakes occur in adults in a dual-task scenario where they must perform both the reorientation and a verbal distractor task. Based on these findings, some theories claim that the acquisition of certain language abilities is a prerequisite for binding geometrical and landmark information (Hermer-Vazquez, Spelke, & Katsnelson, 1999). This conclusion is called into question, however, by numerous findings demonstrating the ability to bind landmark and geometrical information in reorientation tasks across a variety of nonverbal species, such as doves, rhesus monkeys, and goldfish. Many of these studies, however, also replicate the relative prevalence of the use of geometrical over landmark processing in reorientation across species. The overall relevance of allocentric spatial information processing in spatial cognition was also demonstrated in a series of studies investigating the relative preference for egocentric and allocentric spatial strategies in a spatial relational task. All great ape species and human infants preferred allocentric strategies to process spatial relations, indicating the primacy of allocentric over egocentric processing also in spatial relational reasoning (Haun, Rapold, Call, Janzen, & Levinson, 2006).

Social Cognition

Adult humans describe, understand, and explain each other as rational beings that think, feel, and act rationally. The set of abilities we apply to understand each other in this specific way is often referred to as *theory of mind*. In particular, we attribute to each other beliefs and cognitive propositional attitudes that represent the world as it (subjectively) is, and desires and other conative attitudes that represent the world as it (subjectively) should be. Typically, we predict and explain each other's rational actions on the basis of a pair of beliefs and desires ("Why does he hop around so ridiculously?"—"Because he *wants* to get fit and *thinks* this is a good way to do so"). This conceptual scheme, which is core to theory of mind, is therefore often called *belief–desire psychology*.

Children develop their first simple understanding of intentionality no later than their first birthday. By then they have the necessary rudimentary skills to understand others' perceptions and goals. This first basic stage is often referred to as *perception–goal psychology*. For example, in their first year of life, children follow others' gaze and pointing gestures toward unknown targets. As they grow older, children acquire the ability to assess behaviors based on individuals' goals and not only based on superficial, visible features (Behne, Carpenter, Call, & Tomasello, 2005) and an explicit understanding that different individuals have differing perceptual experiences (Moll & Tomasello, 2006). These abilities appear to be shared with other animals, such as birds (Clayton, Emery, & Nathan, 2007) and all great ape species (Hare, Call, Agnetta, & Tomasello, 2000). In the following years, more and more complex forms of social cognition emerge. In the second year of life, children develop the ability to engage in episodes of shared, collective "we-intentionality": Children do not only hold intentional states and attribute them to others but they also share intentional states with others (Rakoczy & Tomasello, 2007). A further milestone in children's sociocognitive development occurs around their fourth birthday, when they acquire the first simple forms of belief–desire psychology: For the first time, children are now able to assign subjective, and potentially false, beliefs to others, and understand that actions can be motivated by such false beliefs. Children also begin to use these skills to lie and thereby instill false beliefs in others (Perner, 1991). Implicit precursors of belief–desire psychology can already be detected in infants using dishabituation paradigms, but these findings remain controversial (Baillargeon, Scott, & He, 2010).

From a comparative point of view, the more complex forms of belief–desire psychology and shared intentionality appear to be largely absent in nonhuman animals. Other species cooperate in apparently complex ways, but closer scrutiny inevitably reveals a lack of shared intentionality, with cooperative activities simply composed out of individual activities executed in parallel (Tomasello et al., 2005). With respect to false-belief understanding, several studies have provided negative results. Nonhuman animals appear not to understand others' beliefs in the same ways humans do (Call & Tomasello, 2008).

3 Some Theoretical Approaches

How can these empirical findings on human cognitive development and on animal cognition be theoretically integrated and explained? Questions concerning the place of

the human mind in the animal kingdom more generally have stirred debates over the centuries, and so far no unique and final answer has emerged. The following sections therefore review and discuss some of the most important theoretical approaches that have figured in these debates. All of these accounts, of course, are firmly rooted in modern evolutionary biology: humans are animals, even if very special ones. The biological basis of the human mind is, like everything in the living world, a product of evolution by natural selection. From a biological point of view, there are thus no radical discontinuities between humans and other animals. Against this background of shared evolutionary assumptions, however, different theoretical accounts differ enormously in their more specific assumptions. While evolutionary continuity in the phylogeny of cognitive capacities is beyond doubt, this does not preclude the possibility that in the cognitive capacities themselves there are radical differences and discontinuities. Some accounts put more emphasis on discontinuities and deep qualitative differences between human thought and other forms of animal cognition (humans have evolved very different and unique capacities). Other accounts, in contrast, put more emphasis on continuities (humans and other animals operate with the same sorts of capacities, and differences pertain to degree rather than kind). Most kinds of accounts indeed acknowledge both continuities and discontinuities.

Radical Difference Accounts

Some theories have aimed at spelling out in more formal detail the traditional idea that human thought is qualitatively and radically different from other forms of animal cognition. One influential account, by Penn et al. (2008), acknowledges that many species use cognitive representations of objects in their environment, of their properties and relations, and of statistical patterns and regularities of events. What is specific to humans, though, is the capacity to go beyond such first-order representations of the environment and form representations of higher-order relations and regularities. Such higher-order representations underlie the formally unique forms of human thinking: In contrast to simpler representational systems, human thought is generative (with finite means, one can think infinitely many new thoughts), compositional (the meaning of complex thoughts is a function of their elements and mode of combination), and systematic (one can flexibly use the same concepts in many different thoughts). The uniquely human capacity for such generative, compositional, and systematic representation reveals itself from early in development—for example, in sophisticated forms of causal reasoning or theory of mind (for which there is no evidence so far that would document comparable abilities in any nonhuman species).

Another influential account assumes that human thought is radically different from any other form of animal cognition in being recursive (Hauser, Chomsky, & Fitch, 2002). Recursive operations are those that can be applied to an outcome of their previous application and that thus open up the possibility of creating an infinite set of structured representations with finite means. Examples include mathematical operations such as the successor function " $x \rightarrow x + 1$," which, applicable infinitely to its previous products, generates the infinite set of the natural numbers. According to this account, only the human mind is equipped with the requisite structures for recursive operations. Three areas where this becomes particularly clear are grammar, theory of mind, and numerical cognition. Regarding grammar, many species can learn some simple syntactic rules for

the sequential combination of elements such as sounds (e.g., extracting the regularity “ABAB” from hearing sounds such as “outch-ough-outch-ough” or “zig-zag-zig-zag”). These rules can mostly be described formally by what are termed *finite state grammars*, which do not involve any recursive operations. More complex rules, however, require what are termed *phrase structure grammars*, which involve recursion. A simple example is learning a rule for sound sequences of the form $A_1A_2A_3B_1B_2B_3$, $A_1A_2A_3A_4B_1B_2B_3B_4$, and so on, where a fixed number (n) of A occurrences is followed by n occurrences of B, for any arbitrary A, B, and n . Empirical evidence from artificial grammar learning shows that human infants can easily learn finite state and phrase structure grammar rules. Comparative evidence, in contrast, suggests that nonhuman primates only master finite state grammar rules, failing to learn phrase structure grammar rules. According to this account, this difference is the most powerful explanation of why only humans acquire a natural language.

Theory of mind is also a recursive capacity since a certain operation, such as “thinks that,” can be freely and recursively applied to products of its previous application in the form of embeddings: “He thinks that (she thinks that (her sister thinks that (her brother thinks that (life without cake is meaningless))))).” And, empirically, there is much good evidence that humans develop flexible forms of such theory of mind ascriptions from fairly early on whereas nonhuman primates may be restricted to more basic forms of theory of mind. Numerical cognition, finally, is clearly recursive in the case of fully fledged human mathematical thought, which is based on the concept of number and its recursive definition through the successor function (“ $x \rightarrow x + 1$ ”). Empirically, much evidence shows that human infants and many other species share basic numerical capacities to exactly individuate small sets and to approximately estimate the sizes of arbitrarily large sets. These capacities, however, fall short of implementing fully fledged numerical understanding since they do not yet involve the concept of number and the successor function. Such fully fledged understanding does emerge, however, in human ontogeny in early childhood, but it seems to be absent even in highly number-trained captive chimpanzees (Carey, 2009).

Core Knowledge and Conceptual Change Accounts

Another class of accounts aims to explain both the nature and scope of shared cognitive capacities and what makes human cognition unique (Carey, 2009; Spelke, 2003). The basic idea is that humans share with many other species evolutionarily more ancient capacities of *core knowledge*. Core knowledge (such as naive physics, numerical cognition, and spatial cognition) refers to basic domain-specific and somewhat encapsulated cognitive capacities. They are typically phylogenetically older, are often adaptations in the evolutionary sense, emerge early in ontogeny, and remain in operation throughout the lifespan without much integration with other forms of cognition. The animal mind, according to this picture, is like a toolbox (or like a Swiss army knife, in another metaphor), involving various cognitive tools for specific purposes (such as navigation, predation, or social life), enabling organisms to cope with their environments. Human cognition, however, is not restricted to such domain-specific capacities. Rather, what happens over ontogenetic time, in processes of fundamental conceptual change, is that information is integrated across domains and thus becomes available in domain-general

ways. Natural language may play a prominent role in these processes in that it provides a conceptual medium for the combination of information from different domains.

These accounts have been best developed in the areas of numerical and spatial cognition. In numerical cognition, human infants share with many other species basic capacities (for the exact individuation of small sets, and for the approximate individuation of arbitrarily large sets). These basic capacities have clear scopes and limits and thus fall short of fully fledged mathematical thinking with numerical concepts. Such concepts, however, emerge in human ontogeny in somewhat protracted fashion when children learn number words. At first, they learn to use these words without much meaning (“one, two, three, four” functions much like “eeny, meeny, miny, mo”). But, after some time, according to these accounts, children begin to integrate their core knowledge representations and the initially meaningless natural language representations to finally yield the semantically productive understanding of the natural number words and concepts.

With regard to spatial cognition, humans share with many other species capacities for orientation and navigation. More specifically, there are supposed to be two separate core knowledge systems for representing different types of spatial information (geometric information and landmark information). Human infants and members of many other species can solve problems that require either one or the other type of information, but they fail tasks that require the combination and integration of both (Hermer & Spelke, 1996; though see the counterevidence mentioned above in the section on spatial cognition). Only later, once they have acquired the relevant linguistic skills, can they achieve this integration and solve these tasks. Language may thus play a role in the acquisition of information integration, but perhaps also in its execution. Some studies show that adult humans only solve these tasks when they have linguistic means available (failing when involved in linguistic dual tasks).

Representational Redescription Accounts

A similar idea, yet in a more Piagetian tradition, has been put forward by Karmiloff-Smith (1992). According to her account, cognitive development can be seen as a multistep process. In Step 1, children, equipped with some biological predispositions and powerful domain-general learning mechanisms, acquire domain-specific competencies on the basis of experience and learning. These competencies remain implicit, are restricted to procedural know-how, are not available to conscious access or verbal report, and generally lack the explicit format of declarative knowledge. This first step characterizes early cognitive development in humans, but it is also shared with many other species that develop highly specialized domain-specific capacities from experience. What makes human cognition special, though, is the so-called representational redescription of Step 2: Humans, according to this account, have an inherent drive to go beyond the implicit procedural capacities acquired in Step 1. Subsequently, these procedural and implicit representations are redescribed into explicit, domain-generally available and consciously accessible declarative representations.

Cultural Learning Accounts

Yet another related kind of account combines the ideas of representational redescription with a more explicitly comparative perspective and Vygotskian tradition (Tomasello,

1999, 2014). According to such accounts, humans and other species, notably primates, share basic cognitive capacities, both domain general (such as memory, learning, problem solving) and domain specific (such as naive physics). What is special about the human mind is social cognition. From early in ontogeny, humans develop special capacities for higher-order intentionality (e.g., one person understands what another sees, wants, thinks, etc.) and for shared intentionality (e.g., two people enter into shared or joint attention, or share intentions in cooperation). These special sociocognitive capacities then lay the groundwork for highly special cooperation, communication, and culture. They are the basis on which humans and only humans acquire the sophisticated social communication system of natural language. Participating in culture, in turn, and particularly the acquisition of a conventionalized compositional language, then transform the initially shared primate cognition.

One kind of evidence for this account comes from large-scale comparative test batteries of cognition. In a typical study, children at 2.5 years, at the beginning of their serious career as members of a linguistic community, and nonhuman great apes were tested with a large battery of cognitive tests (Herrmann, Call, Hernandez-Lloreda, Hare, & Tomasello, 2007). Results revealed that the children and apes performed very similarly in most domains of general and broadly physical cognition (spatial, causal, simple numerical), but the children outperformed the apes considerably in social-cognitive tasks. In subsequent linguistically mediated cognitive development, however, human capacities in physical and general cognition, too, begin to diverge massively from those of other apes. These massive differences, though, arise on the basis of initially shared capacities that then, in the human case, are transformed through language and culture.

SEE ALSO: Evolutionary Biology and the Natural Selection of Behavior; False-Belief Understanding; Metacognition; Studying Cognitive Development in Infants and Toddlers; Studying Cognitive Development in School-Aged Children

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