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Exploring the minds of the great apes: Issues and controversies

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INTRODUCTION

Interest in intelligence has always been intense: it verges on an obsession within Western cultural and scientific traditions, where intelligence reigns as a central defining characteristic of the human species. Interest has always been strongly anthropocentric, but almost as alluring has been contemplating the possibility that there exist, in other worlds or perhaps in other worldly species, other intelligences like our own. Both interests spotlight the nonhuman species most like us, the great apes. Because they are the living species most closely related to humans, they offer important living models of the minds from which modern human intelligence evolved. Scholars ranging from philosophers to linguists, neuropsychologists, and anthropologists have invoked their capacities in developing and justifying their views of the human mind (e.g. Corballis, 1991; Donald, 1991; Gibson & Ingold, 1993; Karmiloff-Smith, 1992).

Our aim in this volume is to present current material that contributes to understanding the minds of the great apes, as they are distinguished from the minds of humans and the minds of other nonhuman primates. Although by now several decades have been devoted to careful research on great apes, laboratory and field studies are still regularly generating rich new material on the range, flexibility, and complexity of great apes' behavior and the depth of their understanding. We have invited contributions from researchers working primarily with great apes, those working with several primate species, developmental psychologists working with humans, and primatologists working primarily on monkey species, in order to highlight contrasts and similarities between great ape, human, and other nonhuman primate intelligence. We expressly invited studies of great apes across a wide range of living conditions, from wild to colony or zoo to laboratory, and the corresponding range of research methods, from observational field studies to controlled laboratory experimentation. Our contributors offer new evidence: from the field, on social cognition in bonobos, complex tool use in chimpanzees, and regional variations in the behavior of chimpanzees with characteristics reminiscent of culture; and from the laboratory, on conflict resolution processes, imitation, ostension, and numerical abilities. Theoretical issues that our contributors address include: the

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most complex levels of ability attained by great apes; the extent to which there are interconnections between great apes' intellectual abilities; the extent to which great apes' social traditions reflect cultural mechanisms; the extent of similarities and differences in intelligence among great ape species; the extent of the intellectual gap between great apes and humans; the extent of the gap between great apes and monkeys; and the extent to which evolutionary, socio-cultural, and developmental perspectives can contribute to understanding great apes' intellect.

Our discussions arise from the view offered by behavioral expressions of intelligence and leave two critical factors in intelligence, the brain and language, as beyond its scope. An assessment of great ape intelligence in terms of the brain would be of great value, but it would require a book in and of itself. We consider great apes' language capacities equally vital to understanding their intelligence, and leave them aside because they have been discussed recently and extensively by others (e.g. Gibson & Ingold, 1993; Parker & Gibson, 1990; Savage-Rumbaugh *et al.*, 1993).

In this opening chapter, we offer a brief historical overview of explorations into the minds of the great apes and an introduction to the two central issues we address in this volume: (a) the *scope* of great ape intellectual abilities, in their breadth and their complexity; (b) the *organization* of these abilities, for instance interdependencies among various abilities and domains, and the developmental, socio-cultural, and evolutionary mechanisms from which it derives. Current themes in exploring *scope* concern great apes' capacities for acquiring a range of specific abilities (e.g. object manipulation, tool use, classification, imitation, pretense, language, deception, mindreading) and the highest levels of complexity they can achieve in each. The *organization* of great ape intelligence is a relatively new issue emerging from findings on the broad scope of great ape intelligence. Themes receiving current attention include the relations and interdependencies among individual intellectual abilities and even domains, and the developmental and socio-cultural processes that influence how these abilities are constructed. Undergoing reevaluation are evolutionary reconstructions, especially concerning the evolutionary forces that could have formed the intelligences of great apes and humans and correspondingly, the models of intelligence that are compatible with comparative evolutionary perspectives.

HISTORICAL AND MODERN VIEWS OF GREAT APE INTELLIGENCE

In the established view, great apes are classified into three genera and four species – orangutan (*Pongo pygmaeus*), gorilla (*Gorilla gorilla*), chimpanzee (*Pan troglodytes*), and bonobo or pygmy chimpanzee (*Pan paniscus*)[1] (e.g. Tuttle, 1986).

The great apes were not clearly distinguished from other nonhuman primates by Western thinkers until the 1600s, but they, along with the other nonhuman primates, had been noticed since antiquity for their unsettling similarity to humans (whence "simians"), particularly in their intellect (French, 1994; Salisbury, 1994). The characteristics of great apes inject ambiguity into neat distinctions between "human" and

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"animal" and the resulting tension is reflected in varying stances about their nature – some periods and some communities have emphasized the differences, others the similarities. For instance, Aristotle knew of nonhuman primates and saw human and animal intelligence as similar except that humans had reasoning abilities beyond the sensorimotor abilities of animals (French, 1994; Gibson, 1993). The early Christians, apparently as a way of distinguishing themselves from the pagan ancients, pronounced unbreachable boundaries. Medieval thinkers returned to a sense of ambiguities from as early as the twelfth century (Janson, 1952; Salisbury, 1994). Medieval scholars likened nonhuman primates to humans because of their imitative and problem-solving abilities, but considered them as imperfect and foolish copies; they did, however, place nonhuman primates in a special category, bridging the divide between humans and animals (Salisbury, 1994). In so doing, they initiated the shift away from views of unbreachable separation between animals and humans and toward views of continuity.

The medieval sense of continuity is considered to have founded the present scientific view of humans as part of the animal kingdom and particularly closely related to great apes (Salisbury, 1994); it now has evolutionary justification. Fossil and molecular evidence show that humans and great apes are related through recent common ancestors, the Hominidae (Begun, 1992; King & Wilson, 1975). Chimpanzees and humans are each others' closest living genealogical relatives; they share a common ancestor unique to themselves more recently than either shares a common ancestor with any other living species. Zoologically, evolutionary relations as close as those between modern humans and chimpanzees would normally result in classifying them together as a single genus, separated only at the species level. Molecular methods further indicate that the relationships are so close as to say humans *are* great apes (e.g. Begun, 1992; for a recent discussion, see Byrne, 1995).

Despite great apes' importance, scientific research into great ape intelligence was sparse until the 1960s. Few volumes dedicated to great ape intelligence have appeared since the pioneering work from the beginning of the twentieth century. The twentieth century history of the social sciences offers important insights into these curious lacunae; because it also set the course of today's questions, we sketch it briefly.

Darwin's (1871) publication of *The Descent of Man and Selection in Relation to Sex* sparked scientific interest in comparative and evolutionary studies of mentality, in the spirit of studying the human mind within Darwin's evolutionary framework. The new disciplines founding much of this work were anthropology and comparative psychology, the former focusing primarily on evolutionary origins of human mentality and the latter fixing on comparative studies of nonhuman species (for discussions, see Antinucci, 1989; Parker, 1990; Tuttle, 1986). This impetus produced significant advances in understanding great ape intelligence, through the work of pioneers such as Yerkes in America, Köhler in Europe, and Kohts in Russia (e.g. Köhler, 1925; Kohts, 1921, 1928; Yerkes, 1916, 1925, 1943; Yerkes & Yerkes, 1929). For instance, Köhler and Yerkes found: great apes could solve problems by "insight"; they could construct and use complex tools; they could abstract, generalize, and infer from their experiences at rudimentary levels; and chimpanzees exhibited the makings of culture.

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This pre-1930 pioneering work was almost the last to concentrate on great ape intelligence until the 1960s, despite its provocative findings. Perhaps through discomfort with the ramifications of evolutionary theory, that humans are not special creatures separated from and above animality, the twentieth century saw a resurgence of discontinuity views attesting to firm boundaries between animal and human abilities. This was manifest in a turn towards logical–positive epistemologies and specialization of scholarship within disciplinary boundaries (Gibson, 1993; Parker, 1990). Both anthropology and comparative psychology adopted these newer views, raising them to mainstream status over most of the middle part of this century (Parker, 1990). In consequence, work on great apes was severely muted. American anthropologists made a place for the study of great apes and other nonhuman primates by the 1930s but within physical rather than cultural anthropology and so out of the mainstream. Comparative psychologists continued some work with great apes but from the perspective of behaviorism. Beyond presuming a human–animal distinction, behaviorists were uninterested in the mind or species differences ("Pigeon, rat, monkey, which is which? It doesn't matter." – Skinner, 1956, p. 230) and many of their practices (reductionist approaches, concern for universal processes, tightly controlled experimentation and rearing conditions, and preference for convenient species) militated against encountering great apes' more complex capacities.

More revealing studies then tended to be maverick ones. The Hayes and the Kelloggs raised chimpanzees in their homes as members of their families to study language and motor development, coincidentally producing findings on the development of discriminatory abilities, imitation, problem-solving, and the effects of "cross-fostering" on apes' intellectual development (Hayes & Hayes, 1951, 1952, 1954; Hayes & Nissen, 1971; Kellogg & Kellogg, 1933). Carpenter (1934, 1938) and Nissen (1931) pioneered field studies of free-living nonhuman primates. This work, peripheral at the time, paved the way for future work on great ape intelligence. Overall, up to the late 1960s, evidence was insufficient to characterize great ape intelligence comparatively (Tuttle, 1986); to some, it appeared that primate learning did not differ from other vertebrate learning, except perhaps in speed (e.g. Warren, 1965). Others, near the end of this era, had a glimmering that there were special qualities to nonhuman primate intelligence: "In both variety and complexity, the problems that fall within the repertory of the primate contrast sharply with those testable on rodent or carnivore" (Harlow, 1951, p. 234).

The 1960s brought revolutionary changes. The cognitive revolution brought back the mind, legitimizing studies of cognition and language as well as reintroducing cognition to comparative psychology under the rubric of animal cognition. Increased international exchange after World War II brought significant innovations. For instance, Japanese scholars, who had developed their own primatological research tradition relatively independently, began to interact more extensively with Western counterparts. This introduced their research traditions, characterized by interests in social structures, the roles of both the individual and the group, and historical views, as well as by long-term field methods and reliance on provisioning (Asquith, 1991, 1994). European ethology emphasized evolutionary perspectives, especially the importance of considering a species' intelligence as an adaptive capacity with qualities evolved in conjunction with

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species-specific contexts and functions. Comparative psychology established methods or measuring complex learning at levels reflecting emergent symbolic abilities (e.g. Rumbaugh, 1969). In physical anthropology, Sherwood Washburn and Louis Leakey helped bring primatology to greater prominence by articulating the significance of the living primates to the evolutionary study of human behavior (Parker, 1990). Developmental psychology, through Jean Piaget, brought views of human intelligence as epigenetic, that is that higher level cognitive abilities are constructed sequentially on the basis of lower level ones, in accordance with physical world and social experiences.

The innovations of the 1960s had significant repercussions. The application of Piaget's developmental approach to great ape and monkey intelligence revealed striking similarities in the patterning of their cognitive development to that of humans, although the focus of study remained at low levels of sensory and motor abilities (e.g. initially through Jolly, 1972; then Mathieu *et al.*, 1976; Chevalier-Skolnikoff, 1977, 1983, 1989 and discussions; Parker, 1977; Redshaw, 1978; Parker & Gibson, 1979; Mathieu & Bergeron, 1981; Chevalier-Skolnikoff *et al.*, 1982; Antinucci, 1989; Russon, 1990; Bard, 1993). Challenges to traditional landmarks of human mentality began as a result of the long-term field studies of each of the three great ape genera initiated during this period (e.g. chimpanzees use and manufacture of tools – Goodall, 1963), studies of language in relation to intelligence (e.g. Miles, 1983; Premack, 1971, 1984), and experimental research suggesting great apes' potential for rudimentary symbolic level processing (e.g. Menzel, 1973, 1978; Premack & Woodruff, 1978; Rumbaugh, 1969). Japanese studies of social traditions in monkeys, which they likened to culture (e.g. Kawai, 1965), contributed to interest in the social dimensions of primate intelligence.

Views and theoretical perspectives changed significantly in light of this work. The argument appeared that primate intelligence is centrally adapted to primates' complex sociality (e.g. Jolly, 1966; Humphrey, 1976) and it subsequently took on major significance (e.g. Byrne & Whiten, 1988). Developmentally oriented findings underlined the importance of ontogeny to primate intelligence. The understanding that has accumulated on great ape cognitive development has come to attract human developmental psychologists, who see the potential of this work to illuminate human cognitive development. As landmarks of human intelligence were found in great apes, interest extended beyond the evolutionary divergence of the hominids to that of the great apes themselves, and led to hypotheses about the evolution of great ape intelligence – for instance, that intelligent tool-assisted extractive foraging on embedded foods constituted their key intellectual adaptation (Parker & Gibson, 1977, 1979). This also increased calls for continuity models of intelligence, as evidence accumulated that human intelligence probably evolved by expanding capacities already present in recent ancestors (e.g. Gibson, 1993). Such changes stimulated further field studies specifically aimed at understanding great ape intelligence, provided impetus to the study of great apes other than chimpanzees, expanded the expressions of intelligence considered researchable, altered the models, the methods and even the definitions of fields concerned with animal intelligence, brought the disciplines of physical anthropology and comparative psychology closer together, and began a reintegration in studies concerned with Tinbergen's causes of

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behavior – proximate mechanisms, ontogeny, phylogeny, and evolutionary function (Parker, 1990; Tinbergen, 1963).

The scope of great ape intelligence

The post-1960s research increased appreciation for great apes' capacities, but the full scope of their intelligence, both in breadth (the range of problem areas in which their intelligence is expressed) and complexity (the levels of sophistication they attain), has not yet been established.

At least three research perspectives guide explorations concerning scope. A first focuses on the constellation of intellectual abilities that may characterize the great ape–human divide, such as tool use and tool manufacture, imitation, sense of self, pedagogy, and culture. Although rudiments of virtually all the abilities traditionally considered hallmarks of human intelligence are now accepted as within great apes' scope (Gibson, 1993), scholars continue to probe these abilities in great apes for qualitative distinctions and for suggestions about the evolutionary antecedents to the human forms. A second perspective derives from researchers who study primate groups and social dynamics. It focuses attention on abilities for handling social problems, such as conflict resolution (de Waal, 1989; Kummer, 1967), theory of mind (e.g. Premack & Woodruff, 1978), imitation (Kawai, 1965; Mitchell, 1987; Whiten & Ham, 1992), social communication, deception (Byrne & Whiten, 1988; Mitchell & Thompson, 1986), and teaching (Boesch, 1991; Caro & Hauser, 1992). The third perspective is that of Piagetian developmental psychology, which considers yet another array of intellectual abilities (e.g. object concept, causal reasoning, logicomathematical reasoning). Research undertaken from this perspective explores the constructive processes and changes involved in building great ape intellectual abilities. An additional advantage of this perspective is that it conceptualizes intellectual abilities as multileveled and ordered in terms of complexity, an important view in considering our second issue, the organization of great ape intelligence.

The turn towards continuity and away from discontinuity views has had its own impact on this issue. First, great ape–human intellectual differences are being reformulated in terms of degree rather than of kind, accepting that the great apes and humans share critical abilities at rudimentary levels (Gibson, 1993), and attention is now focused on the highest levels of an ability attained by great apes or by other nonhuman primates. Secondly, human rather than animal models are increasingly considered the more appropriate as the basis for comparative assessments of great ape abilities. The ultimate benchmarks for comparison are human abilities because questions about intelligence tend to be anthropocentric; in addition, the great apes are more closely related to humans than they are to any other animal species; and only human models address great apes' higher level abilities. A rehabilitated anthropomorphism is then one of the many products of this shift to continuity views. Among its more lighthearted manifestations is an insistence for anthropomorphic descriptions of great ape behavior, as, for instance, deception (Mitchell & Thompson, 1986), "Machiavellian intelligence" (Byrne & Whiten, 1988) and "chimpanzee politics" (de Waal, 1982).

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The significance of developmental approaches to understanding the scope of great apes' intellectual abilities is increasingly apparent. Clearly, for instance, it is inappropriate to compare the performance of the most frequently used great ape subjects, individuals 3–5 years old, with adult humans: the former are infants and young juveniles with immature abilities, whereas the latter possess mature intellectual abilities and skills. We also now recognize that great apes do not fully master some of their intellectually based skills until near adolescence, from 7–10 years of age in the wild (e.g. Boesch & Boesch, 1993; Matsuzawa, 1994). Further, researchers find considerable variability in great apes' performances, especially in tasks demanding high-level cognitive abilities. This variability tends to correlate with rearing conditions, prior experience, and age; indeed, some consider that great apes may not attain certain abilities, like language and symbolic level imitation, except under particular rearing conditions (e.g. Boesch, 1991; Tomasello *et al.*, 1993b; Whiten & Ham, 1992). For these reasons, developmental considerations are currently prominent in investigations into the scope of great ape intelligence (e.g. see Chapters 10, 11, 12, 13, 14, 15, 16, and 17).

In this context, we consider briefly current issues concerning the scope (breadth and complexity) of great ape intelligence.

Understanding of the *breadth* of great apes' intellectual span continues to expand, even now, with each new ability considered opening new avenues for understanding great ape intelligence. Most of our contributors delve into the intricacies of established abilities (e.g. causal reasoning as seen through tool use, object manipulation, and food processing; logicomathematical reasoning such as classification and quantification; social abilities such as imitation, pretense, deception, mindreading, mirror-self-recognition, self-awareness, teaching, and cooperation). Others discuss newer indices of sophisticated intelligence, particularly in the domain of social intelligence where the phenomena that index complex cognition are not yet clearly identified (e.g. reconciliation and consolation (Chapter 4); ostension (Chapter 6); self-related phenomena (Chapter 15); secondary representation (Chapter 14); use of tools to solve social problems (Chapter 9)).

Regarding *complexity*, various abilities initially treated as representing a single achievement (self-recognition, theory of mind, true imitation) are being reconstrued as multileveled ones. To illustrate, primates' intelligent tool use may involve several achievements reflecting multiple levels of cognitive sophistication. On the basis of the monkey species that have been tested, primarily cebus and macaques, monkeys may not understand the relationships involved in tool-mediated problem-solving whereas the great apes and humans do (Visalberghi & Trinca, 1989); great apes sometimes use sets of tools rather than single tools (see McGrew, 1992) whereas monkeys very rarely do (there exists only one report of tool set use in cebus monkeys – Westergaard & Suomi, 1993); and only great apes have been found to use a tool to modify or to make a second tool (Matsuzawa, 1991; Toth *et al.*, 1993; Wright, 1972). Each of these great ape variations in tool use is considered to reflect higher level cognitive abilities. Likewise, other shared abilities (e.g. tactical deception, imitative learning, self-awareness, mindreading) are being reconstrued as multileveled and devolving from a multiplicity of mechanisms varying in cognitive complexity (e.g. Byrne, 1995; Mitchell, 1987; Parker *et al.*, 1994;

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Whiten & Byrne, 1988). Several of our contributors discuss the levels at which great apes express a given ability or identify variation in the levels at which a given ability can be expressed – causality (Chapters 3 and 12), self-concept (Chapter 15), logicomathematical abilities (Chapters 8 and 12), conflict resolution (Chapter 4), imitation-related phenomena (Chapters 3, 5, 7, 13, 14 and 16), teaching (Chapter 16), and metarepresentation (Chapter 14). Of central interest are the highest levels of an ability that great apes or other nonhuman primates attain.

Although great apes' abilities fall well short of those achieved by humans, evidence that all the great apes can handle such tasks as rudimentary language, insightful or tool-assisted problem-solving, and abstract learning is seriously challenging traditional views that their reach is bounded by symbolic level processing (e.g. Gardner *et al.*, 1989; Lethmate, 1982; McGrew, 1992; Miles, 1983; Meador *et al.*, 1987; Mignault, 1985; Parker *et al.*, 1994; Patterson & Cohn, 1990; Premack & Woodruff, 1978; Savage-Rumbaugh *et al.*, 1993). Since the mid-1980s, research has increasingly targeted great apes' abilities beyond sensorimotor and into symbolic levels. Several researchers now argue that great apes have demonstrated the capacity for rudimentary symbolic level processing in several abilities, such as imitation (Custance & Bard, 1994; Russon & Galdikas, 1993; Tomasello *et al.*, 1993b; Whiten & Custance, 1994), deception (Byrne & Whiten, 1988), tool use and object manipulation (e.g. Matsuzawa, 1994; McGrew, 1992; Russon & Galdikas, 1992), and classification (Langer, 1993). Similarly, researchers argue that the great apes achieve abilities that hinge on symbolic processes, such as self-awareness, pretense, analogical reasoning, quantification, demonstration teaching, and mindreading (e.g. Boesch, 1991; Boysen & Berntson, 1990; Gardner *et al.*, 1989; Langer, 1993; Meador *et al.*, 1987; Parker *et al.*, 1994; Povinelli *et al.*, 1992; Premack, 1984; Whiten, 1991). Among the most striking of the realizations emerging from this work is that *all* the great apes share these intellectual capacities; what differs is their tendency to express them.

Many of our contributors present further evidence and arguments concerning great ape capacities at symbolic levels – Chapters 10, 16, 18, and 19 (proto-cultural processes), Chapter 15 (self-related concepts), Chapter 8 (logicomathematical reasoning about number and quantity), Chapter 12 (logicomathematical and causal reasoning), Chapter 13 (imitation, deception, and pretense), Chapter 16 (imitation, self-awareness, and teaching), Chapters 5 and 7 (imitation), and Chapter 4 (consolation). Significantly, other nonhuman primates have not yet shown abilities beyond sensorimotor levels (Antinucci, 1989; Visalberghi & Trinca, 1989; Chapters 2, 3, and 4).

The implication is that the significant move beyond sensorimotor to symbolic thought evolved with the ancestors of the great apes, not the ancestors of humans. In Aristotle's terms, this would qualify great apes as rational and creative thinkers, like humans. This also supports the possibility that these hallmark abilities distinguish great ape from other nonhuman primate intelligence. Contention around this view is high. Our contributors do not themselves agree on the intellectual scope of great apes (compare Chapters 7, 13, 14, and 16 with Chapter 17). Some argue that great apes do not attain the highest level abilities except when raised with intensive human tutoring (e.g. Tomasello *et al.*, 1993b; Chapter 17); others, that their most complex abilities are

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attained in the wild (e.g. Chapter 18). Neither is the distinction between great ape and monkey intelligence well established (compare Chapter 2 with Chapter 3).

The organization of great ape intelligence

Increasing appreciation for the scope of great ape intelligence has raised the question of how to understand their particular constellation of abilities. Do the intellectual abilities that have been demonstrated by great apes represent a simple collection or are they interrelated; if they are interrelated, in what way and at what levels? Empirical evidence remains relatively limited because research has tended to consider individual abilities in isolation rather than in relation to one another.

The possibilities concerning interrelationships range between two poles: great ape intelligence comprises independent, problem-specific, module-like abilities or it constitutes some generalized capacity. Both positions have been advocated as models for human intelligence (e.g. Fodor, 1983; Gibson, 1993; Sternberg, 1990). Intermediate possibilities include interconnections among discrete abilities at some intermediate level, such as large problem domains (e.g. social, ecological). Modularity or problem-specificity models are the most strongly advocated for learning in nonhuman species (e.g. Davey, 1989; Hirschfield & Gelman, 1994a), including monkeys, based on evidence that their abilities for handling social and ecological problems are domain-specific and mutually inaccessible (Cheney & Seyfarth, 1990; Langer, 1989). Generality–modularity issues, however, are not yet resolved for either humans or nonhumans (e.g. Greenfield, 1991; Hirschfield & Gelman, 1994b; Karmiloff-Smith, 1992); and although earlier studies generalized across nonhuman primates, more recently investigators have focused on differences between monkeys and great apes. Evidence on the organization of great ape abilities could play a key role in these debates.

Research on great apes has focused on two possibilities, interconnections among abilities (e.g. between individual abilities, within domains, or between domains – see Gibson, 1993; Langer, 1989), or some overarching, generalized capacity such as hierarchical mental construction that generates individual abilities centrally (e.g. Byrne, 1994a; Galdikas & Vasey, 1992; Greenfield, 1991; Russon & Galdikas, 1994).

Those exploring interconnections assess interplay within particular subsets of abilities, such as co-occurrences, interdependencies, or developmental parallels. Evidence exists for links among some individual abilities (e.g. self-awareness and imitation co-occur in great apes (see Parker *et al.*, 1994); language training may enhance chimpanzees' performance on analogy problems (see Premack, 1984)). Particular attention has been devoted to the relations between the large domains of social and ecological intelligence. The focus of attention shifted from ecological to social intelligence in the late 1980s. Early discussions aimed at establishing the relative primacy of social versus ecological intelligence in primate evolution (e.g. Byrne & Whiten, 1988; Dunbar, 1992). Within the primates, however, the great apes require an added consideration: great apes' feeding niche (e.g. embedded foods) is considered to have further shaped their intelligence (e.g. one capable of handling extractive foraging – see Byrne & Byrne, 1991; Parker & Gibson, 1977). While researchers continue to recognize the distinctive qualities of the

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intellectual abilities within each domain, they are now, more intensively, examining interconnections between the two domains (e.g. how great apes' imitative abilities contribute to their technological ones). Several of our contributors offer further demonstrations or arguments for interplay among individual abilities (e.g. see Chapters 5, 11, 13, 15, and 16), within domains (e.g. Chapters 13 and 14), and between domains (Chapters 9, 16, 18, and 19).

The ways in which abilities are constructed play a central determining role in the organizational patterns that appear. Developmental models therefore offer important perspectives on how intellectual abilities may interrelate. These models are particularly important to primates, who, with prolonged immaturity, rely heavily on joint influences of environment, genetic programming, and the socio-cultural milieu for constructing many behavioral achievements (e.g. Scarr & McCartney, 1983). Of equal importance is the possibility that something akin to culture is a contributor, a possibility that is hotly debated. Evolutionary perspectives suggest another view on how great ape intelligence is organized.

Developmental considerations

Developmental perspectives offer a variety of insights into the organization of great apes' intellectual abilities. For instance, the sequential emergence, developmentally, of a subset of abilities suggests structural interdependencies among them, in that later emerging abilities depend on the earlier ones; developmental parallels, particularly synchronized progress across abilities, suggest those abilities are coordinated or integrated, whereas asynchronous progress suggests more isolated, problem-specific organization. A number of researchers argue for particular sequentially-based interdependencies (e.g. imitation, pretense, and teaching (see Chapters 13, 14, 16, and 19); or imitation and self-awareness (see Parker *et al.*, 1994)). Synchronous development is considered to characterize the early development of human cognitive abilities. In contrast, asynchronous development has been reported for monkeys (Antinucci, 1989; Cheney & Seyfarth, 1990; Langer, 1993; Parker, 1977) and some degree of synchrony, for great apes (e.g. Mathieu & Bergeron, 1981; Russon, 1990; Langer, 1993). Langer (Chapter 12) compares this developmental synchrony across great apes, humans, and some monkeys, and argues for its significance in the evolution of complex cognitive capacities. Developmental parallels could also support centralized models, if they reflect similar construction processes for discrete abilities. The patterning underlying the parallels may determine which model is favored (e.g. in Chapter 12, Langer favors interconnectivity interpretations for his findings). More conclusive assessments await more intense study of the co-occurrences and developmental synchonies among great apes' abilities across problem areas and even across domains.

Developmental models that portray cognitive abilities as multileveled are useful for assessing great ape intelligence in comparative perspective (e.g. Antinucci, 1989; Mitchell, 1987; Parker & Gibson, 1979, 1990; Whiten, 1991). Especially useful are models portraying cognitive development as a sequential epigenetic process because they facilitate scaling intellectual levels in a fashion amenable to evolutionary analyses.

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