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Development of Manipulations with Objects in Ape and Human Infants

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Object manipulations were studied in infants (8-11 months of age) of three primate species: human; common chimpanzee (*Pan troglodytes*); and bonobo or pygmy chimpanzee (*Pan paniscus*). Observations of free play were videotaped and the complexity of manipulations (based on Piagetian theory) and functional usage of modes (both hands and feet) was described. Results indicated that the chimpanzee mouthed (without grasping) more frequently than both the bonobo and human infants. For all infants, half of the object-oriented behaviors consisted of active manipulations of a single object. However, for the apes, most of these manipulations consisted of simple holding and/or moving the objects against a substrate. In contrast, the human infant more frequently extracted an object from the background and, furthermore, moved the object or explored its unique characteristics. Additionally, the human infant exhibited a richness and differentation in the use of modes that was not observed in ape infants. These results are discussed within an evolutionary perspective.

1. Introduction

The importance of object manipulation for the development of human intelligence has been recognized by many psychologists (e.g., Gesell, 1940), and has been theorized in the pioneering work of Piaget (1953, 1954). The Piagetian approach provides three kinds of behavioral patterns to describe the ontogenetic development of human infants' interactions with inanimate objects. These patterns are called "circular reactions" because they imply repetitions of actions (a) related to the body ("primary circular reaction"), (b) on objects ("secondary circular reaction"), and (c) between objects themselves ("tertiary circular reaction"). During the first 18 months of life, the form of object manipulations progresses from primary to tertiary circular reactions. This developmental change has found experimental confirmation in many studies of human infants (e.g., Fenson *et al.*, 1976; Knopp, 1976; Bates, 1979; Belsky & Most, 1981). These studies show that by nine months of age, object play is becoming increasingly complex, changing from simple, undifferentiated manipulations to explorations of the unique properties of objects and, later, culminates in combinatorial and symbolic play.

Several studies have used the Piagetian curriculum to test object permanence in apes (see Vauclair, 1982, for a review). The developmental sequence that culminates in object permanence is followed by both human and non-human primates. Furthermore, non-human infants attain object permanence at an earlier age than human infants. However, with regard to the development of object manipulation (tertiary circular reaction and constructive play), both comparative and developmental studies have found that ape infants did not show the kind of complex manipulatory behaviors demonstrated by humans (Kellogg & Kellogg, 1933; Redshaw, 1978; Antinucci, 1981).

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Most comparative studies of cognition in primates are based either on formal testing, such as the use of standardized tests (Uzgiris & Hunt, 1975), or on observations of behaviors with non-standard objects (see, for example, Chevalier-Skolnikoff, 1977). To date, there have not been any strictly comparative studies which use the same set of objects in an informal, or free play, situation. Therefore, there is a need for the present study, which investigates cognition in three primate species provided with the same set of objects in a free-play situation.

The goal of this study was twofold. First, we wanted to describe the type and, especially, the complexity of object manipulations that occur in infants, from 7–11 months of age, of three different primate species, human, chimpanzee and bonobo. An evolutionary perspective suggested a second comparative question; specifically, whether human and nonhuman primates use their hands in functionally similar or different ways.

One theory of the evolution of hominids (Marshack, 1982) suggested that more complex uses of intelligence emerged either in concert with, or as a result of, hominids using their hands more frequently and in more integrated and differentiated ways. Therefore, we were interested in characterizing the activity of each hand. The periods of time in which both hands were active were distinguished from the stream of behavior in order to investigate bimanually asymmetric and co-ordinated functions.

2. Methods

Subjects

Three different primate species were used: human; common chimpanzee (*Pan troglodytes*); and bonobo (*Pan paniscus*). All subjects were seven lunar months of age at the beginning of the study and 12 lunar months of age at the end of the study (standardized lunar month = 28 days). This age range encompasses the developmental period in humans, when attention to objects is high and there is a transition between simple and complex manipulatory behaviors. The human infant was female; the ape infants were male. Female humans of this age have been shown to be less vigorous than males in their manipulations of objects (Knopp, 1976). Thus, if everything else were equal, the selection of a female human would give manipulatory advantage to the male ape infants.

Setting

The human (Aleah) and one chimpanzee infant (Chesley) were observed in one room of their living quarters in the presence of their natural mothers. The other chimpanzee infant (Joseph), raised in the nursery of the Yerkes Regional Primate Research Center, was observed in the playroom of the nursery in the presence of an adult human (female caretaker). The bonobo infant (Kanzi) was observed in one section of the living quarters, with an adult female bonobo and a female human caretaker. Although the adult bonobo was not the infant's natural mother, this pair had been together since the infant was two days old, and the female probably behaved toward the infant as she behaved toward her own offspring.

All infants were familiar with their surroundings prior to the beginning of the study. The environments in which the infants were raised can be ranked with regard to the richness and complexity of stimuli present on a daily basis. Ranking the settings from most to least complex results in the following order: human home; indoor/outdoor enclosures of the bonobo; nursery; indoor/outdoor enclosure of the infant chimpanzee and mother pair.

Apparatus

Subjects were provided with identical sets of objects (see Figure 1). This set of objects was unique for all subjects, i.e., they encountered these objects only in this study. The human, however, did have previous contact with functionally similar objects, e.g., cups, but cups were contacted on a daily basis by all the apes as well. This set of objects was constantly available to all subjects. For the human, the objects were placed in a corner of a room. Reports from the mother indicate that Aleah contacted the objects almost exclusively during the observation sessions.

Pretesting with two subadult males demonstrated that the objects were "chimp-proof", i.e., virtually indestructible. These objects were chosen, or designed, to provide the opportunity for multiple single and combinatory uses. The circular, plastic dolly had wheels, which allowed it to be used to transport objects, and small holes in the plastic that permitted the insertion of the two metal sticks. The sticks, differing in length and shape (straight or bent), provided the opportunity for instrumental use, e.g., use of the stick as a rake with which to obtain out-of-reach objects.

The metal plate and cup allowed the subjects to demonstrate conventional usage, e.g., drinking from the cup or symbolic play (pretend eating from the plate). Complex object–object relations could be expressed with the use of nesting cubes; for example, inserting a small cube into the next larger size cube, and so forth.

Observations were videotaped with a Hitachi camera and recorded on a Sony Betamax color system. The videotapes were duplicated and running time (minutes, seconds, and tenths of a second) was superimposed in the center of the top portion of the image.

Procedure

Each subject was videotaped for 15 minutes. A maximum of 10 minutes was allowed for the subject to "warm up" (especially necessary for the nursery infant); however, filming began as soon as the subject appeared oriented to the objects. It was believed that 15 minutes represented the maximum amount of time the subjects would remain focused on the objects at one sitting.

The human adult (mother or caretaker) was not instructed to act in a specific way. She was asked to behave as she usually did in the presence of the infant and the toys.

The initial goal was to videotape one session every two or three weeks for each subject from 7–12 months of age. However, this goal was not attained for all subjects and, therefore, only the four sessions that were taped once per month for each subject, from the age of 8–11 lunar months, are considered.

Each videotape was viewed and two coding systems were applied. The type and complexity of object manipulation were coded with the first system. Piagetian theory provided a model for classifying complexity. Our system, similar to those used for other human studies (e.g., Belsky & Most, 1981; Rubenstein & Howes, 1976), was designed to capture a range of behaviors from simple visual orientation toward objects, secondary circular reactions and their coordination, to conventional (e.g., cultural) uses of objects. "Culture" is defined here as the contingent environment experienced by the subjects. The complexity codes are listed and defined in Table 1.

The complexity codes were hierarchically organized according to the patterning of behaviors within each level of circular reaction. We assigned visual behavior directed toward objects as the least complex and active manipulation with the hands or feet as the

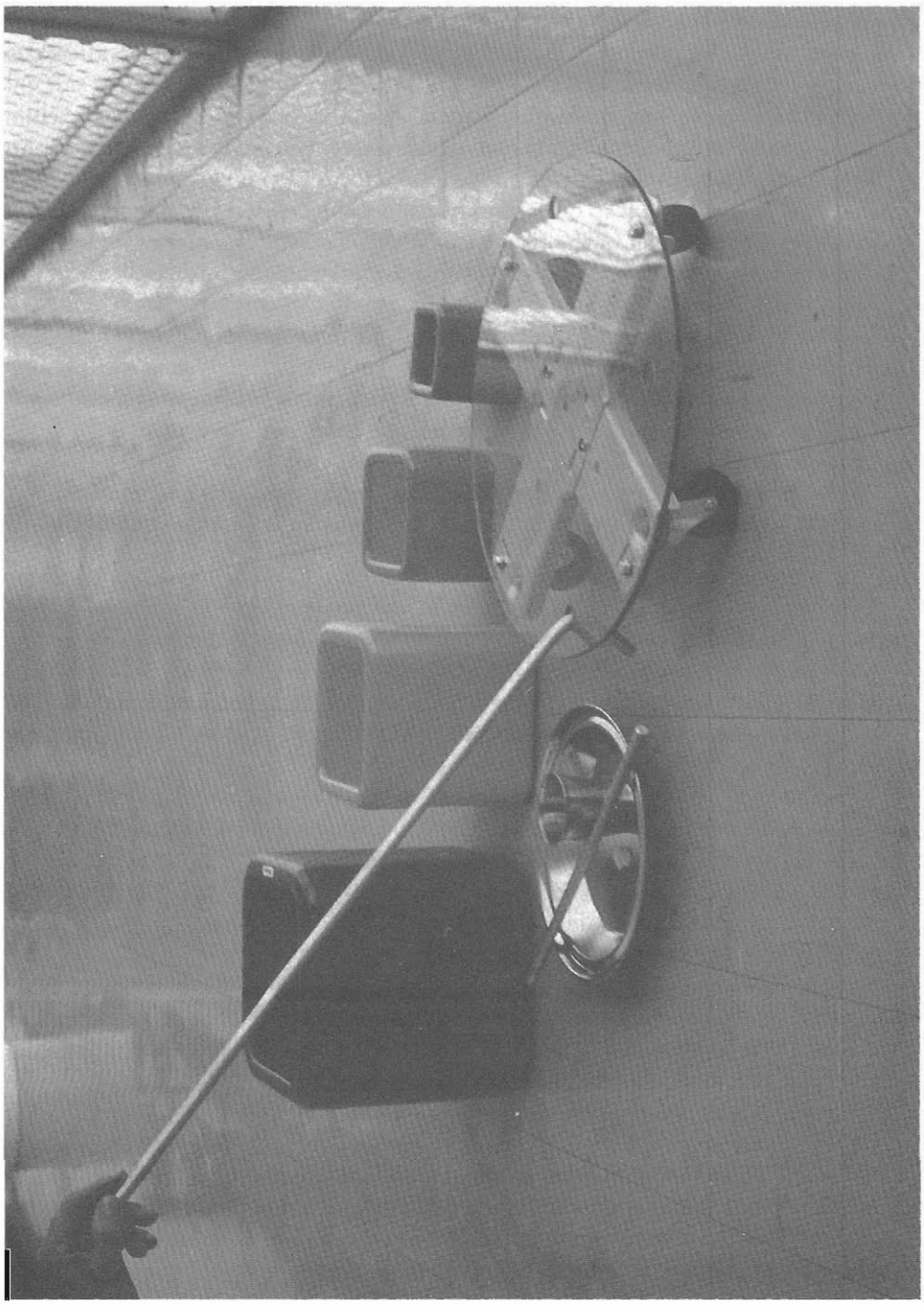

Figure 1. Set of objects used in the study, including one dolly (48 cm diameter), one aluminum stick (76 cm long), one short aluminum stick (38 cm long), four open cubes (25 × 25 cm, 20 × 20 cm, 15 × 15 cm and 10 × 10 cm), one metal plate (26 cm diameter), and one metal cup (7 cm diameter, 8 cm high).

Table 1 **Description of behavioral complexity levels**

Level	Behavior	Description
?	Unknown	Either the object-directed behavior is not visible or a judgement about its complexity level cannot be made
1	Look	Watching an object that is in motion, with no physical contact (example: visually following movement of a rolling stick)
2	Sniff	Placement of the nose adjacent to or touching an object, with no other physical contact
3	Mouth	Contact with lips, teeth or tongue on an object, *without grasping*
4	Passive Manipulation	Placement of part of the body against an object, without grasping or causing the object to move (examples: leaning an elbow against a large cube; stepping on a plate)
5	Active Manipulation	Activity by the hands or feet directed toward an object and/or movement of the object as a result of contact with the hands or feet (examples: tapping; slapping; grasping; pushing; pulling; waving an object in the air)
6	Simple Relation	Placement of one object in global relation to another object (examples: holding a small stick while banging it against the outside of a large cube; dropping a cup)
7	Complex Relation	Placement of one object in specific relation to another object (examples: putting a small cube into a larger cube; throwing a stick to the ground)
8	Instrumental-ization	Use of one object as a means to act on another object (examples: using a stick to push a dolly; using a dolly to transport a cup)
9	Construction	Complex use of objects to build a structure (example: stacking cubes, one on top of the other)
10	Conventional Use	Use of an object in a culturally-accepted way (example: drinking from an empty cup)

most complex secondary circular reactions. Mouthing involves more extensive contact with an object than does sniffing; therefore, sniffing and mouthing were ranked Level 2 and Level 3, respectively. Two categories of coordination of secondary circular reactions involved either undifferentiated (Level 6) or specific (Level 7) combinations of two objects. This distinction reflects differences in underlying cognitive organization. Higher level combinatory uses of objects consist either of instrumentalization, a form of tertiary circular reaction, or of functional use. Functional use of objects was divided into constructional and conventional use.

The complexity codes were applied to each object-oriented behavior. Both manual and non-manual contacts were recorded. For each object-oriented behavior, the complexity of the manipulation was coded according to a hierarchical, mutually exclusive and exhaustive system (Table 1). The coding system was hierarchical in the sense that the most complex, or highest level, behavior directed to an object by each hand or foot was recorded. For example, if the subject was holding one end of a stick in his right hand and was mouthing the other end of the stick, only the grasp with the right hand was recorded; grasping was defined as more complex than mouthing. However, if the right hand was grasping a cube and the stick was in the mouth, then both behaviors would be recorded; right hand actively manipulating the cube and mouth contacting the stick. The time at which the behavior began (onset) and ended (offset), the complexity code, mode, and object were recorded for each event.

The second coding system involved bimanual co-ordination and asymmetry. Bimanual asymmetry was assessed by the application of the complexity codes, described above,

separately to each mode: right hand (RH); left hand (LH); and foot (F). The foot mode was included primarily to allow for the maximal manipulatory expression of chimpanzees, which possess the capacity for fine motor control in their toes and feet. Therefore, bimanual asymmetries in complexity of activity could be measured. The co-ordination of activity between hands (or between hands and feet) was assessed by means of two measures: overlap and transfer. An instance of overlap was counted when any combination of right hand, left hand, and/or foot events occurred concurrently. These periods of co-occurrence were categorized according to whether the manipulatory complexity and/or objects involved in the events were the same or different. This coding system was designed to assess frequency of occurrence of hands or feet acting together in a manner that was coordinated (e.g., acting on the same object) or differentiated (e.g, different behaviors applied to the same or different objects). Another means by which actions between modes could be co-ordinated was exhibited in the transfer of an object from one hand or foot to another. Thus, an additional pass was made through the videotapes to record each instance in which an object was exchanged between the hands (or between hand and foot).

Re-coding

The final broad area of analysis was undertaken subsequent to the completion of the coding systems described above. The majority of behaviors for each subject and each session were coded in the category, Active Manipulation. We felt that this category was too broad and that finer distinctions should be made for the following reason. Both simple tapping of the fingers against an object and fine manual explorations of the details of an object (its unique characteristics) were originally classified as Active Manipulation. A more detailed classification system was designed to illuminate qualitative differences in active manipulation between subjects. Therefore, each event originally coded as Active Manipulation was reviewed and re-coded into one of seven hierarchical, mutually exclusive and exhaustive types of active manipulation (see Table 2 for listing and definitions).

These categories reflect a hierarchy of attending to objects as separate entities. At the lowest level, an object is grasped and treated as different in identity from the other objects; however, the object could only be a part of another object, i.e., not discrete. This simple behavior (Hold) indicates a lack of knowledge of the object's discreteness. When the

Table 2 **Definitions of categories used in the breakdown of "Active Manipulation"**

Category	Definition
Hold	Simple grasping of one object
Push/Pull	Grasping of one object while moving it along a substrate (example: moving a dolly backward and forward along the floor)
Extract	Grasping one object and moving it so that the activity is directed toward that object in particular, apart and different from the background (example: picking up a plate from the floor with one hand and grasping it with the other hand)
Wave/Shake	Making an object move once it has been extracted (example: picking up a stick and waving in the air)
Explore	Fine, detailed movements directed toward the unique characteristics of an object (example: moving a finger around a small metal bolt that protrudes from the plastic top of a dolly)

subject is able to make the object move (Push/Pull), he is one step closer to learning the identity of the object. However, it is clearly indicated that the entire object is a unity, independent of any other object, only when the object can be Extracted. The next category, Wave/Shake, reflects an understanding both of the discreteness of the object and its ability to be individually manipulated. The final, and most complex, type of active manipulation is Explore. This behavior reflects not only a knowledge of the object as an entity, but also reflects an investigation into those properties of an object which make that object individually distinct.

Inter-observer/Intra-observer Agreement

Agreement between different coders (inter-observer agreement) and between the same coder at different times (intra-observer agreement) was assessed with the Kappa statistic (Cohen, 1960). Percentage agreement was not used alone due to its tendency to overestimate reliability when chance agreement is high (Hollenbeck, 1978). The Kappa statistic corrects for agreement due simply to chance and is applied to the entire coding scheme. The acceptable criterion was set at 0·70, and all Kappa statistics were substantially above this basal criterion. One observer served as the standard coder and recorded data for all sessions and all subjects. Intraobserver agreement was assessed, resulting in a Kappa statistic of 0·81 (percentage agreement = 91·7). Inter-observer agreement was assessed independently by two different observers. Average agreement between the first and standard observers was 0·84 (Kappa: range = 0·77–0·91; average percentage agreement = 92·9; range = 89·8–96·1, n = 5). Agreement between the second and standard observers also was assessed (Kappa: 0·90; percentage agreement = 94·9). Additionally, a single test was conducted which compared the agreement between the two non-standard observers (Kappa: 0·91; percentage agreement = 95·7).

3. Results

It was found that Chesley, the chimpanzee infant that was with his mother, did not act on the objects. The reasons for the lack of data are not clear; however, we suspect that the mother's behavior played a major role (Bard & Vauclair, submitted). Assuming that the sampled time of day was inappropriate, midway through the study, the authors observed this animal for eight hours on one day in an attempt to record all his actions with the objects. However, the infant failed to reward this vigilance, i.e., he did not act on the objects. Subsequent to the conclusion of this study, the chimpanzee infant was observed for 45-minute sessions, and pencil-and-paper narratives were recorded which did include instances of interactions with objects. Thus, at 15½ months of age, Chesley was acting on the objects. He displayed behaviors as complex as Simple Relations (see Table 1). The most complex behaviors were interactions with the sticks (the most commonly contacted objects), and included, for example, pushing the stick out of the cage and banging both sticks together. Since these latter observations were noted in broad descriptions when the subject was older, they are not included in further analyses.

Type and Complexity of Object Manipulation

Application of the coding system for complexity level resulted in the data presented in Table 3. Instances of construction were never observed and, therefore, are not included in the analysis.

Table 3 **Frequency of behavioral complexity levels**

Subject	Age (lun. mo: days)	Complexity level									
		1	2	3	4	5	6	7	8	10	?
Aleah	8:18	12	0	0	2	158	9	4	0	4	2
	9:24	18	0	0	0	94	12	0	0	0	0
	10:10	18	0	0	4	117	26	0	1	0	0
	11:02	13	0	0	1	123	16	6	0	0	1
Percentage of total		9·5	0·0	0·0	1·1	76·8	9·8	1·6	0·2	0·6	0·5
Joseph	8:08	20	10	8	0	17	2	0	0	0	1
	9:13	22	10	15	1	19	0	0	0	0	0
	10:16	2	9	29	1	83	10	0	0	2	2
	11:06	9	9	33	1	61	6	0	0	0	1
Percentage of total		13·8	9·9	22·2	0·8	47·0	4·7	0·0	0·0	0·5	1·0
Kanzi	8:14	0	0	0	2	23	0	0	0	0	1
	9:09	6	1	0	0	16	0	0	0	0	3
	10:02	2	0	0	0	35	0	0	0	0	4
	11:02	1	4	1	0	13	0	0	0	0	0
Percentage of total		8·0	4·5	0·9	1·8	77·7	0·0	0·0	0·0	0·0	7·1

Aleah, the human subject, exhibited consistently high frequencies of active manipulation. A total of 120–200 object-oriented actions was observed during each session, and between 70% and 83% of these were classified as Active Manipulations. Aleah demonstrated an approximately equal distribution of both more and less complex behaviors in each session (assuming that active manipulation is average in complexity). Aleah was never observed to sniff and did not mouth an object without first actively manipulating it with her hand(s). A rank ordering of the duration and frequency with which each object was contacted revealed that Aleah interacted most frequently with the dolly and often utilized the small and large sticks.

A more detailed analysis of the type of active manipulation (Table 4) revealed that, for the first session, more than half of Aleah's active manipulations were of one type, simple holding of an object. More than 12% of her manipulations involved extracting the objects from the background, and almost 15% involved Active Movement and Exploration. In subsequent sessions, the proportion of simple holding decreased and the proportion of behaviors involving extraction, especially those with added movements (i.e., waving and shaking), increased. Considering all sessions as a whole, Aleah engaged most frequently in active manipulations of two kinds, simple holding (36%) and active movements (31%).

Joseph, the nursery-raised infant chimpanzee, exhibited a total of 58 and 67 object-oriented behaviors in the first two sessions, respectively. Of these instances, over one-third consisted of watching objects and approximately one-third consisted of active manipulations of objects with the hands and feet. The remaining one-third predominantly consisted of sniffing and mouthing. Joseph demonstrated complex schemes twice during the first session, which consisted of simple relations between two objects. During the last two sessions, he exhibited a total of 138 and 120 object-oriented behaviors, 60% and 51%

Table 4 **Breakdown of the category 'Active Manipulation' (Frequency per session and overall percentage of total behaviors)**

Subject	Age (lun. mo: days)	Hold	Push/Pull	Extract	Wave/Shake	Explore
Aleah	8:18	90	13	20	20	15
	9:24	29	20	11	33	1
	10:10	22	9	8	67	11
	11:02	35	27	25	30	6
Percentage of total		35·8	14·0	13·0	30·5	6·7
Joseph	8:08	9	2	5	1	0
	9:13	14	4	1	0	0
	10:16	23	50	6	0	4
	11:06	48	8	5	0	0
Percentage of total		5·2	35·6	9·4	0·6	2·2
Kanzi	8:14	15	1	5	2	0
	9:09	12	4	0	0	0
	10:02	23	7	3	1	1
	11:02	11	2	0	0	0
Percentage of total		70·1	16·1	9·1	3·4	1·1

of which were active manipulations. "Looks" dropped to less than 10% of the total behaviors recorded, and the relative amount of sniffing and mouthing remained at approximately 30%. The number of complex behaviors increased to 12 and six in the third and fourth sessions, respectively. These complex behaviors primarily were simple relations, but Joseph demonstrated two instances of conventional use with the cup during the third session. A rank ordering of the duration and frequency with which each object was contacted revealed that Joseph interacted most frequently with the dolly. He also frequently contacted the plate and spent long periods of time with the largest cube.

A breakdown of Joseph's active manipulations (Table 4) indicated that almost all active manipulations involved either simple holding or pushing/pulling an object along a substrate, e.g., the floor (average = 84·8; range = 64·7–94·7%). Extracting an object from the background accounted for approximately one-third of the manipulations during the first session and less than 10% of those for subsequent sessions. Active movements and explorations were observed infrequently in the first and third sessions. Considering all sessions as a whole, Joseph's most frequent active manipulations involved simple holding (52%) and pushing/pulling (36%).

Kanzi, the bonobo, exhibited a total of between 19 and 41 object-oriented behaviors in each of the four sessions. The majority of these infrequent behaviors consisted of active manipulations (61–88% in each session). Kanzi did not demonstrate any complex manipulations involving relations between objects, instrumentalization or conventional use. He occasionally watched objects (as high as 23% of the total object-oriented behaviors in the second session), and demonstrated sniffing and mouthing of objects (26% of the total in the fourth session). A rank ordering of the objects contacted by Kanzi demonstrated that the small stick was contacted most frequently, followed by occasional interactions with the smallest and largest cubes.

Table 4 indicates that Kanzi's active manipulations could be categorized primarily as simple holdings (65-92%). In the first session, Kanzi extracted objects from the background (21·7%) and on two occasions, actively moved objects. In the second and fourth sessions, all active manipulations consisted either of simple holding or pushing/pulling. On one occasion during the third session, Kanzi exhibited active movement of an extracted object, and once, explored the details of an object. Considering all sessions as a whole, Kanzi most frequently exhibited simple holding (70·1%) and often moved objects along a substrate(16·1%).

In summary, Aleah demonstrated much higher frequencies of object-oriented behaviors, overall, than the infant chimpanzees, and higher frequencies, specifically, in the categories of Active Manipulation and Simple Relation. More complex behaviors, i.e. complex relations, instrumentalization and conventional use, were observed in the human infant; these behaviors occurred infrequently, if at all, in Joseph, the common chimpanzee. Kanzi, the infant bonobo, did not exhibit behaviors more complex than active manipulation. Kanzi exhibited the lowest frequency of total object-oriented behaviors; however, the proportion of these behaviors that were classified as active manipulation was comparable to that of Aleah (77 and 78%, respectively). Joseph exhibited a lower percentage of active manipulation (47%) and demonstrated the highest frequencies of sniffing and mouthing. Aleah's non-Active Manipulations were distributed evenly between simpler behaviors

Table 5 **Frequencies in use of modes acting alone or together for each subject in each session**

		Mode							
Subject	Session	RH	LH	F	RH+LH	RH+F	LH+F	RH+LH+F	Exc
Aleah	1	93	82	4	106	3	0	2	22
	2	47	39	20	47	19	3	16	16
	3	46	82	20	39	0	12	0	23
	4	54	91	2	43	0	1	0	6
Relative frequencies					0·440	0·077	0·047	0·031	
Joseph	1	12	7	0	0	0	0	0	0
	2	15	4	1	3	1	0	0	0
	3	52	37	8	46	2	1	2	0
	4	32	30	6	9	12	3	6	0
Relative frequencies					0·307	0·119	0·043	0·039	
Kanzi	1	6	11	9	0	4	3	1	0
	2	5	4	8	0	1	0	0	0
	3	9	10	15	2	0	0	5	0
	4	5	2	5	1	1	0	0	0
Relative frequencies					0·058	0·097	0·047	0·067	

RH = right hand.
LH = left hand.
F = foot or feet.
Exc = exchange of object from one hand to the other hand.

(mostly looking) and more complex behaviors (mostly simple relations). This distribution pattern was not observed in Kanzi; his non-active manipulations consisted of simpler behaviors. Although the majority of Joseph's non-Active Manipulations consisted of simpler behaviors, approximately 5% of his behaviors were more complex.

Biomodal Asymmetry and Co-ordination

The frequency with which the hands and feet were used to manipulate objects is presented in Table 5. Aleah used her left hand more often than she used her right hand(51% *vs* 41%, respectively) and, surprisingly, she used her feet for almost 8% of her manipulatory behaviors. Joseph used his feet for 7·4% of his object manipulations. Joseph used his right hand to manipulate objects slightly more frequently (54%) than he used his left hand (38%), whereas Kanzi used both hands less, but equally, often. More than 40% of Kanzi's manipulations involved activity with the feet.

Differences among the subjects were evident in their co-ordination of bimodal activity. Aleah used both hands for 44% of her object manipulations, compared to 31% for Joseph and less than 6% for Kanzi. Aleah also exhibited higher proportions of co-ordination between one hand and the feet (54·8%) than did Joseph (26·2%) and, especially, Kanzi (14·4%). The relative frequency with which feet and both hands acted together was slightly higher for Kanzi (6·7%) than for either Aleah (3·1%) or Joseph (3·9%).

The greatest difference in the use of hands and feet between Aleah and the ape infants was represented by the frequency of exchange, i.e., the transfer of an object from one hand (or foot) to another during active manipulation: Aleah exchanged an object 67 times, whereas neither Joseph nor Kanzi demonstrated any transfers.

Table 6

Percentage of total overlaps in terms of similarities and differences of objects and behaviors for each mode

Subject	Mode	=B–=O	=B–≠O	≠B–=O	≠B–≠O
Aleah	RH/LH	52·23	21·31	1·71	5·50
	RH/F	3·44	3·44	0·34	0·34
	LH/F	3·44	1·03	0·69	0·34
	RH/LH/F	1·03	4·46	0·00	0·69
Joseph	RH/LH	17·65	37·65	0·00	12·94
	RH/F	3·53	12·94	0·00	1·17
	LH/F	0·00	4·70	0·00	0·00
	RH/LH/F	2·35	7·06	0·00	0·00
Kanzi	RH/LH	16·67	0·00	0·00	0·00
	RH/F	27·78	0·00	0·00	5·55
	LH/F	16·67	0·00	0·00	0·00
	RH/LH/F	33·33	0·00	0·00	0·00

=B–=O: same behaviors and same objects.
=B–≠O: same behaviors and different objects.
≠B–=O: different behaviors and same objects.
≠B–≠O: different behaviors and different objects.

RH: right hand.
LH: left hand.
F: foot or feet.

When an instance of overlap between the activity of hands and/or feet occurred, records were maintained regarding whether the complexity of the behaviors exhibited in the different modes were the same or different and, also, whether the same different objects were contacted. Therefore, there were four different types of overlaps in terms of behaviors and objects used. The proportion of each type of overlap that occurred for each bimodal overlap is presented in Table 6.

Aleah predominantly used both hands together, rather than in combination with the feet. Most of these overlaps involved both hands demonstrating behaviors of the same complexity level directed toward the same object. Additionally, Aleah demonstrated overlaps in which the same complexity level was exhibited with the right and left hands, but with the use of different objects. Ranked third, in terms of frequency, were cases in which different levels of behavior were used to act on different objects. During the early sessions, the complexity level of behaviors involved in this latter type of overlap included Passive Manipulation, Active Manipulation and Simple Relation. In the fourth session, there were two instances of overlap that involved Active Manipulation with one hand and Complex Relation with the other hand.

The majority of Joseph's overlaps (68·2%) also involved both hands. More than one-third of these overlaps involved each hand acting with the same complexity level (most occurring in the category of Active Manipulation), with the hands directed toward different objects. The cases of overlaps in which Joseph applied different behaviors with the right and left hands (10 instances) toward different objects involved Active Manipulation with one hand and Simple Relation with the other hand. There was one instance in which one hand was activily manipulating an object and the other hand was using an object in a conventional way (i.e., drinking from the cup).

Only one of Kanzi's overlaps was of the type in which the same level of behavioral complexity was applied to the same object by each mode. One-third of his overlaps involved feet and both hands acting together. Approximately 28% of Kanzi's total overlaps involved the right hand and the feet. The one instance of overlap in which different complexity levels with different objects were exhibited involved the right hand actively manipulating one object while the foot was passively contacting another object.

4. Discussion

Developmental studies of exploration and play by human infants have shown that the period around nine months of age is characterized by the transition from simple manipulation to relational and functional uses of objects (Fenson *et al.*, 1976; Zelazo & Kearsley, 1980; Belsky & Most, 1981). Relational acts were defined as the capacity to combine or relate two objects, whereas functional behaviors described the capacity to extract some unique piece of information and to use it in an appropriate way (e.g., conventionally, or as an instrument). In these respects, Aleah's manipulations are comparable with available data on larger samples of human infants. Thus, Aleah can be considered to be a reliable reference point for comparison with apes.

An overview of the four subjects in the present study can lead to the following description of similarities and differences among these species. The present study was based on a minimal sample and, therefore, the descriptive results must be viewed as preliminary. Variation among individuals can be quite large in both humans and great apes and, therefore, caution is advised in overgeneralizing from these results. (See for example the

marked difference between the two common chimpanzees in the number of object manipulations.)

Infant of both species of chimpanzees sniff and mouth objects without grasping them. These behaviors were systematically displayed by the common chimpanzee upon first contacting new objects. Mouthing has been reported to be a prevalent way of interacting with objects in many species of non-human primates (Parker, 1974*a*, *b*; Candland, French & Johnson, 1978). The sensitivity and flexibility of the mouth enable chimpanzees to use their lips and tongues to explore fine details of objects. It is interesting to note that the bonobo infant used this type of approach much less frequently than did the common chimpanzee infant. The bonobo and chimpanzee infants primarily demonstrated those types of behaviors which are typical in human infants at 6–8 months of age, i.e., simple and repetitive manipulations of a single object (in Piagetian terminology, secondary circular reactions). Maturational levels do differ among these species and, thus, comparing ontogeny by age alone might be questioned. More extensive comparative data are needed in order to index development with age. Age was used in the present study because it is necessary at this stage of the comparative/developmental field to have a measure from which we can obtain the conversions to developmental or maturational scales.

The quality and quantity of manipulations differed between Aleah and the apes. Aleah's active manipulations occurred mostly "above the ground" and were exemplified both by the frequencies with which extracted objects were moved and by the circulation of objects between her hands. These activities were rarely observed in the ape infants.

Consideration of modal co-ordinations revealed additional important interspecies differences. The human infant exhibited greater richness and differentiation in the use of the modes to manipulate objects than was seen in the ape infants. This feature was demonstrated in the high total frequency and more numerous instances of each type of overlap in terms of behaviors and objects. Furthermore, this flexibility in the activity of the human infant appeared in the multiple instances when objects were transferred from one hand to the other. The presence in humans of such co-ordinated patterns of modal behavior might have "the function of constructing the capacity for representation of complementary gestures of the arms and hands relative to the objects" (De Schonen, 1977, p. 154), making possible the emergence of such complex activities as knot-tying, plaiting, etc. These characteristics also could be of evolutionary significance, in the manner of Marshack's (1982) model of hominization based on two-handed competence.

Settings for the subjects differed not only in terms of environmental stimulation, but also in terms of the social context. The purpose of this study was to assess manipulations in which objects are used for their own sakes. However, objects also can be used in social games (e.g., play) and as a means of attaining social goals (e.g., getting attention). This type of object use has been observed among both human infants (Bates, 1976) and chimpanzees (Plooij, 1976). Moreover, the social context plays an important role in determining the forms to be taken by object manipulations.*

* Competent adults can monitor and orchestrate the infant's manipulative activities. Further analyses of our observations on these subjects, which focus on the communicative context, are reported elsewhere (Bard & Vauclair, submitted).

Portions of the data reported herein were presented at the IXth Congress of the International Primatological Society held in Atlanta, Georgia, U.S.A., 8–13 August 1982.

In conclusion, our study clearly demonstrated that human and non-human infants differed in the way they explored and manipulated objects. Our results are consistent with the reports of other studies on chimpanzees (for example, Mathieu & Bergeron, 1981). Moreover, our coding system permitted the detection of differences and similarities that have not been reported previously: (a) objects are mouthed without being held in the hands more frequently in the chimpanzee infant than in the bonobo infant; and (b) both chimpanzee and bonobo infants manipulate objects without extracting them from their background, in contrast to the frequent extraction of objects by the human infant. This latter feature might have evolutionary importance, since use of discrete and movable objects makes them susceptible to many kinds of arrangements and combinations, such as construction and tool use. It should be noted that these advanced skills do develop in chimpanzees, since adults of this species have been observed to use objects in complex ways, e.g. tool use. Prerequisite behaviors from which later complex skills develop are evident in ape and human infants at 8–11 months of age. However, only human infants of this age demonstrate the first clear instances of these complex manipulations with objects.

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