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ABSTRACT

A chimpanzee (Pan troglodytes), trained to count foods and objects by using Arabic numbers, demonstrated the ability to sum arrays of 0-4 food items placed in 2 of 3 possible sites. To address representational use of numbers, we next baited sites with Arabic numbers as stimuli. In both cases performance was significantly above chance from the first sessions, which suggests that without explicit training in combining arrays, the animal was able to select the correct arithmetic sum for arrays of foods or Arabic numbers under novel test conditions. These findings demonstrate that counting strategies and the representational use of numbers lie within the cognitive domain of the chimpanzee and compare favorably with the spontaneous use of addition algorithms demonstrated in preschool children.

Sensitivity to specific quantities has been demonstrated in a wide range of species, including rats, raccoons, chimpanzees, and human neonates (Antell & Keating, 1983; Boysen, 1987; Boysen & Berntson, 1986b; Capaldi & Miller, 1988; Davis, 1984; Rumbaugh, Savage-Rumbaugh, Hopkins, Washburn, & Runfeldt, 1987; Woodruff & Premack, 1981). Counting, however, like other cognitive behaviors such as language, has often been defined to exclude nonhuman numerical competence (Davis & Memmott, 1982). The revitalization of studies of animal cognition has provided an emerging theoretical framework for examining the phylogenetic continuum of information processing (Hulse, Fowler, & Honig, 1978; Roitblat, Bever, & Terrace, 1984). Thus, studies of number use in animals may provide an evolutionary perspective on the emergence of human cognition, including numerical and mathematical capabilities.

The chimpanzee *(Pan troglodytes)* shares a notable portion of genetic material with humans (Goldman, Giri, & O'Brien, 1987; Goodman, Braunitzer, Stangl, & Shrank, 1983) and has demonstrated complex abilities with various symbol systems (Gardner & Gardner, 1984; Premack, 1986; Savage-Rumbaugh, 1986). It is plausible that the biological overlap between the two species may be similarly reflected in underlying cognitive processes that support such representational skills. Thus, the chimpanzee may be an optimal animal model for exploring new dimensions of cognitive function, including numerical capacities. In this study we report evidence to suggest counting and related number reasoning abilities in a juvenile chimpanzee.

Method

Subject

A 5.8-year-old female chimpanzee *(Pan troglodytes),* Sheba, was the subject of our study. She had been cross-fostered in a human home from 4 months to 2.5 years of age. At that time Sheba was obtained from the Columbus Zoological Gardens and has since been immersed in training on a range of conceptual skills, including such tasks as one-to-one-correspondence, color discriminations, the use of colors as attributes, slide recognition, drawing (Boysen, Berntson, & Prentice, 1987), cross-modal discriminations, a vigilance task of sustained attention (Berntson & Boysen, 1987), and same-different concepts. In addition, Sheba served as the subject for a study of the heart rate indexes of recognition of humans and chimpanzees (Boysen & Berntson, 1986a, in press-a). Although none of these tasks were directly related to subsequent numerical studies (with the exception of the initial one-to-one task correspondence described below), such early training likely provided Sheba with a variety of conceptual experiences that contributed in part to her subsequent acquisition of number concepts.

Preliminary Number Training Procedure

One-to-one correspondence task. The first structured task that Sheba learned (at age 2.5 years) was a simple one-to-one correspondence task. She was required to place one and only one object in each of six compartments of a divided tray and readily acquired the skill with candy and praise as reinforcers.

Modified one-to-one correspondence. In this first phase of numbers training (begun at 4 years of age), Sheba learned to select round placards to which a corresponding number of metal disks were affixed, in response to 1, 2, or 3 food items (Figure 1). During training, Sheba and her teacher-experimenter typically sat directly across from one another, which maximized the opportunities for the teacher to coordinate Sheba's attention to the task. Food items were always presented on the same tray and were placed in a variety of positions. As the experimenter placed the food items on the tray one at a time, she always counted aloud. If Sheba did not respond immediately by selecting one of the three lids, the experimenter recounted the items aloud, touching each one as she counted. If Sheba was correct, she was permitted to eat the candy on the tray. For approximately 6 weeks during the initial acquisition phase, the experimenter wore mirrored sunglasses to discourage Sheba's potential attempts to use social cues. Once Sheba was responding reliably, the glasses were no longer necessary. After Sheba reached criterion performance (90% correct for two successive sessions; Table 1), the round placards were replaced with plastic placards to which black Arabic numbers had been affixed (see Figure 1), and training continued until Sheba was able to label arrays of 1 -3 foods (see Table 1; Boysen & Berntson, in press-b). The positions of all number alternatives were random throughout both phases of training in order to control for position preferences. Once criterion performance had been reached, training was initiated for number comprehension.

Number comprehension. Training for the comprehension of number symbols began with the presentation of individual numbers 1, 2, and 3 on a video monitor, with the response placards placed in a horizontal row in front of the screen (Figure 2). As with the labeling tasks, positions for all choice stimuli were random. The chimpanzee was required to attend to the number displayed and to select the corresponding placard bearing 1, 2, or 3 disks. If Sheba was correct, one candy was placed on each of the markers on the placard as the experimenter counted aloud. The subject was then permitted to eat the candy. The acquisition of receptive (comprehension) skills with Arabic numbers 1, 2, and 3 is depicted in Table 2.

Introduction of 4 and 0. The number 4 was introduced next, directly as an Arabic number in the labeling-task format, followed by the number 0 (Table 3). The same presentation tray was always used to display items to be counted, and thus an empty tray indicated a 0 trial. As the number 4 was introduced and Sheba's performance deteriorated somewhat (see Table 3), she was observed to begin to touch, point to, or move items in the array before making her final decision. Such motor tagging and partitioning have been noted in very young children in the early stages of learning to count. It has been proposed that such behaviors permit children to keep track of those items already counted and those which remain to be counted (Gelman & Gallistel, 1978). These tagging behaviors emerged spontaneously in Sheba after approximately 18 months of number training, during which her teacher had consistently tagged items presented for counting. The functional significance of these behaviors for Sheba has not yet been determined, but she has continued to reliably tag items during all subsequent number-related tasks (Figure 3; Boysen & Berntson, in press-b).

Figure 1. Stimuli used in modified one-to-one correspondence task (top) and for introduction of Arabic numbers (bottom).

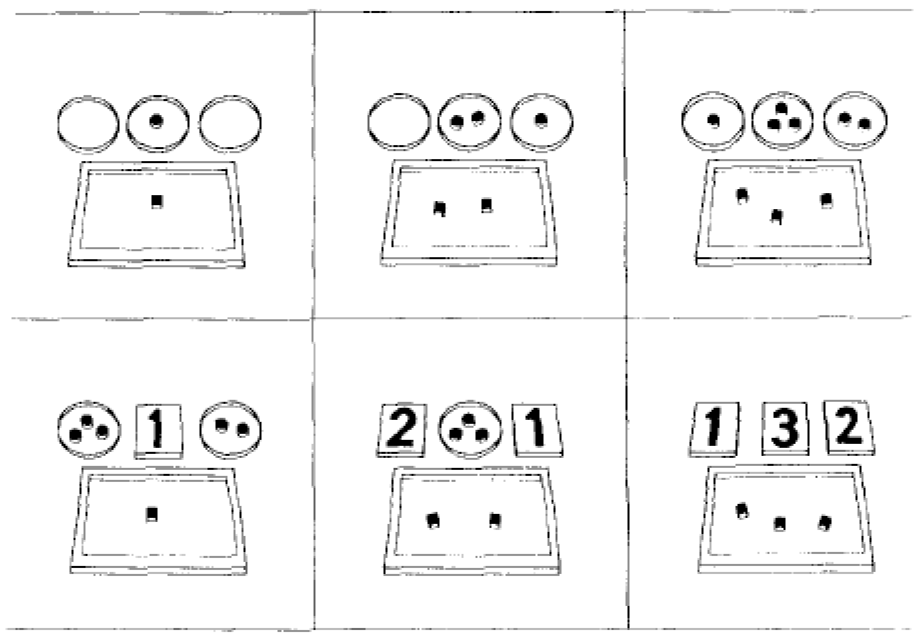


Table 1. Trials to Criterion for One-to-One Correspondence and Introduction of Arabic Numbers

Measure	Trials
One-to-one correspondence	
Match 1 disk	150
Match 2 disks	50
Match 1 or 2 disks	975
Match 1, 2, or 3 disks	300
Introduction of Arabic numbers	
1, 2, and 3	325

Note. Criterion for all measures was 90% correct responses for two successive sessions.

Numerical labeling of object arrays. Up to this point, all labeling tasks with numbers involved the presentation of edible arrays, either homogeneous (arrays of gumdrops, M&M's, or grapes) or heterogeneous combinations of such items. To determine Sheba's ability to generalize number labels to inedible objects, we presented common household items such as a flashlight battery, spool, and other junk objects in collections of 1-3 items. Sheba had not been asked to label arrays of objects prior to this test, nor was she familiar with the items used. Testing was completed under double-blind conditions, with Experimenter 1 seated behind a barrier with Sheba. The Arabic number placards were placed in a horizontal row, in ordinal sequence in front of her. The numbers were not visible to Experimenter 2, who sat on the other side of the barrier and presented the objects on the same tray used in the previous counting tasks. During each trial Sheba came around the barrier, examined the tray, and returned to the other side to make her number selection. Once a choice was made, Experimenter 1 announced her response verbally, and Experimenter 2 verified whether she was correct or incorrect. If correct, she received a matching number of small candies. Sheba was able to correctly assign the appropriate Arabic number to 13 of 15 arrays, for an overall performance of 87% under double-blind, novel test conditions. These data indicate that Sheba was able to directly transfer her skills at labeling homogeneous and heterogeneous arrays of edibles to labeling heterogenous arrays of objects.

To further evaluate Sheba's flexibility with number concepts, in this study we examined her counting ability in two novel paradigms.

Experiment 1

Functional Counting Task

To provide a more naturalistic opportunity for counting, we devised a functional counting task during which one or two of three possible food sites in the laboratory were baited with oranges. Three separate locations were designated as food sites. These sites, a section of a tree stump, a stainless steel food bin about 1 m off the ground, and a plastic dishpan were approximately 2 m apart. Together with the starting platform, they formed an approximate square (Figure 4). The cache of oranges at a given site was not visible from either the start platform (or from any of the other food sites) when Sheba made her number selection from Point A (see Figure 4).

Sheba was required to move among all three sites and then to select the correct Arabic symbol that represented the total number of oranges hidden. For the first three trials of the first session, the experimenter held Sheba's hand and walked with her to all three sites, drawing her attention to the hidden oranges by pointing and indicating verbally. When they returned to the start platform (Point A), Sheba made her choice from among the number alternatives 1-4 (placed in ordinal sequence). On all subsequent trials Sheba was free to move among the sites as she chose, while the experimenter sat at the start platform, facing away from the food sites. Sheba usually completed visits to the three sites within 15-20 s. If she did not return to the start platform within approximately 20 s, the experimenter verbally encouraged her to do so.

When making her number choice during training trials, Sheba faced the experimenter, with the number alternatives in a row between them. She was required to make direct physical contact with the number she chose. This typically entailed touching the placard with her left index finger and maintaining that position until the experimenter acknowledged whether or not her response was correct. For blind testing the experimenter sat behind Sheba, so that the experimenter could not initially see her selection, and Sheba could not see the experimenter (see Figure 5). Because the prior training had required that Sheba maintain physical contact with the selected number until given feedback by the experimenter, during blind trials the experimenter waited 3-5 s before looking around in front of Sheba to see what choice had been made. Sheba was approached by the experimenter from either her right side or her left side randomly, so that the experimenter's movements could not contribute to predicting toward which end of the number sequence the correct response placard was positioned.

Results and Discussion

We had hypothesized that given her success on previous number-related tasks, Sheba could be taught to perform the functional counting task. However, her performance during the initial session was significantly above chance (Table 4). Thus, no specific additional training was necessary for Sheba to generalize to the numerous novel demands of the functional task. For example, prior training or testing conditions had not required that the animal (a) move from site to site, (b) attend to different quantities separated in time and space, (c) maintain a representation in memory of the number of items seen (food items were always visible during previous tasks but were not visible during response selection in this study); or (d) select the correct symbol corresponding to the total number of items presented as two separate quantities.

Sheba's subsequent performance on the functional counting task, also presented in Table 4, continued to be highly significant. The last four sessions (18-21) used 1-4 oranges and were blind, as described above. Her continued significant performance under the blind conditions suggested that Sheba could not only sum arrays that were no longer perceptually available but that she could demonstrate such abilities under novel test conditions.

Although Sheba did not receive explicit training on combining arrays, her performance may potentially be explained through her application of previously acquired counting strategies or addition algorithms. Growing evidence from studies with very young children suggests that preschool children with no formal schooling in arithmetic possess some understanding of addition and subtraction (Carpenter & Moser, 1982; Fuson, 1982; Groen & Resnick, 1977; Starkey & Gelman, 1982). Whereas much of the early research on addition concentrated on number-fact problems and whether particular types of problems would facilitate or interfere with subsequent problem learning, studies of the last decade have addressed the use of counting algorithms by young children (Groen & Parkman, 1972; Svenson & Broquist, 1975; Woods, Resnick, & Groen, 1975). Although the use of algorithms by children has been noted previously (e.g., Woody, 1931) and described in some detail (Ilg & Ames, 1951), such potential abilities in preschool children may have been overlooked until more recent reports brought to light the skills that younger children do possess, as opposed to those which they lack (Gelman & Gallistel, 1978). Thus, children as young as 4 ½ years old were found to apply spontaneously a more efficient algorithm than one taught by experimenters to solve simple addition problems (Groen & Resnick, 1977). In a related study, Starkey and Gelman (1982) found that young children (particularly 4- and 5-year-olds) would use counting algorithms even when objects were added or subtracted from arrays that were hidden from view. This suggests that the child may have an implicit understanding of some properties of arithmetic, namely that addition increases numerosity and subtraction decreases numerosity (Starkey & Gelman, 1982). Young children's addition errors typically deviated by + 1, suggesting that counting errors were responsible for deviations from the correct total (Gelman & Gallistel, 1978; Ilg & Ames, 1951; Starkey & Gelman, 1982).

It seems plausible, given her success with counting arrays of foods and objects, that Sheba might apply a counting strategy the first time she was confronted with two separate arrays. Sheba's training of Arabic numbers was serial, so that each number added to her repertoire met the requirements of $X + 1$, with X being the previously acquired number in the series. Thus, the ordinal characteristics of numbers and the additive component of increasing numerosity were implicit facets of the training procedures, just as they are in a typical counting situation between a knowledgeable adult and a child learning to count. It is not unreasonable to propose that Sheba was able to count each array and to arrive at a correct total, particularly with the small numbers involved.

The spontaneous application of addition algorithms by very young children provides potential validation for Sheba's performance, even though it is not possible at this time to determine the precise nature of her counting strategy. On the basis of the children's literature, we can hypothesize several possible strategies that could provide Sheba with the correct total for such problems (Fuson, 1982; Starkey & Gelman, 1982). She could, for example, view both arrays and begin her count from the larger array, a strategy for which there is considerable data for young children (Fuson, 1982; Groen & Parkman, 1972; Groen & Resnick, 1977; Ilg & Ames, 1951; Starkey & Gelman, 1982). This approach is known as *counting-on.* With this strategy the counting may begin with the number that represents the entire first array (its cardinal number) and continue until all the elements of the second array have been enumerated (Fuson, 1982). Thus, for an array of 1 orange and 3 oranges, Sheba could encode 1 after viewing the first array of oranges and then count-on from 1 when encountering the second array of 3 oranges to 4, which would be selected to represent the total of the two arrays. A more efficient version of the counting-on strategy is to begin the count with the larger of the two arrays rather than the first addend (Fuson, 1982). In this case Sheba would begin her count with 3, representing the larger of the two arrays, continue her count with the second array of 1, and arrive at the sum of 4.

Figure 2. Stimuli and position of chimpanzee during number comprehension training.

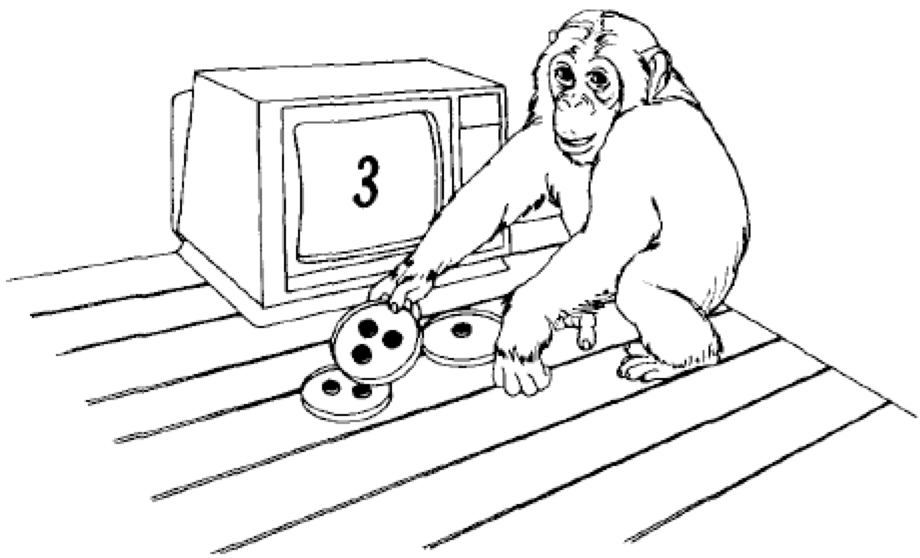


Table 2. Acquisition of Number Comprehension Skills

Session	No. of trials	% of correct responses
1	25 (25)	44
2	21 (46)	81
3	25 (71)	76
4	20 (91)	50
5	22 (113)	91
6	25 (138)	56
7	17 (155)	59
8	25 (180)	52
9	25 (205)	68
10	25 (230)	76
11	17 (247)	82
12	20 (267)	85

Note. Cumulative number of trials is shown in parentheses. The overall percentage of correct responses across the 12 sessions was 75%.

Table 3. Introduction of Numbers 0 and 4

Days	% of correct responses	
	Trials with new number	All trials
	Introduction of 0	
1-4	67	75
5-8	78	75
9-12	68	70
13-16	100	66
	Introduction of 4	
1-4	65	57
5-8	62	51
9-12	87	69
13-16	74	68

Figure 3. Motor tagging by Sheba of three apples in an array.

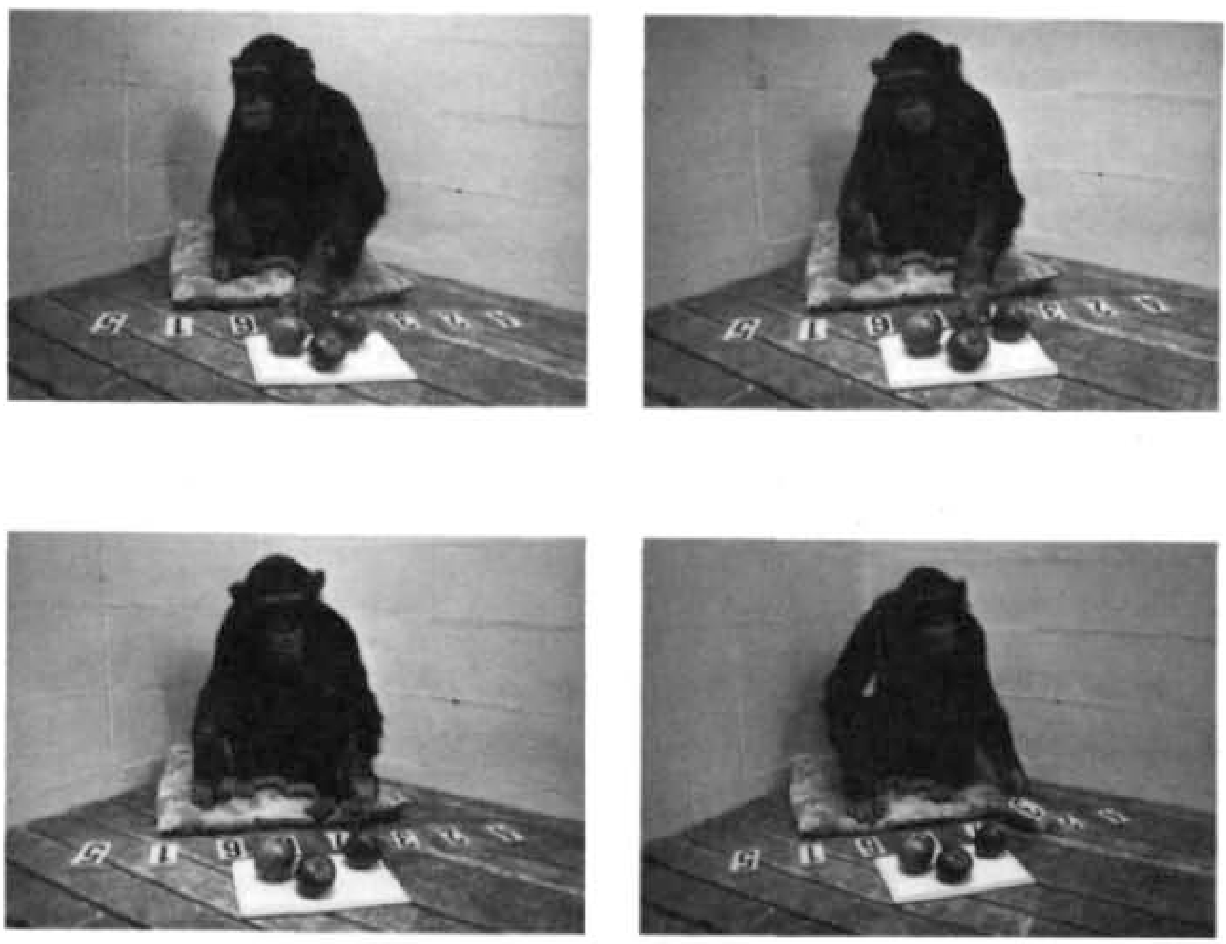


Figure 4. Experimental setting for functional counting task.

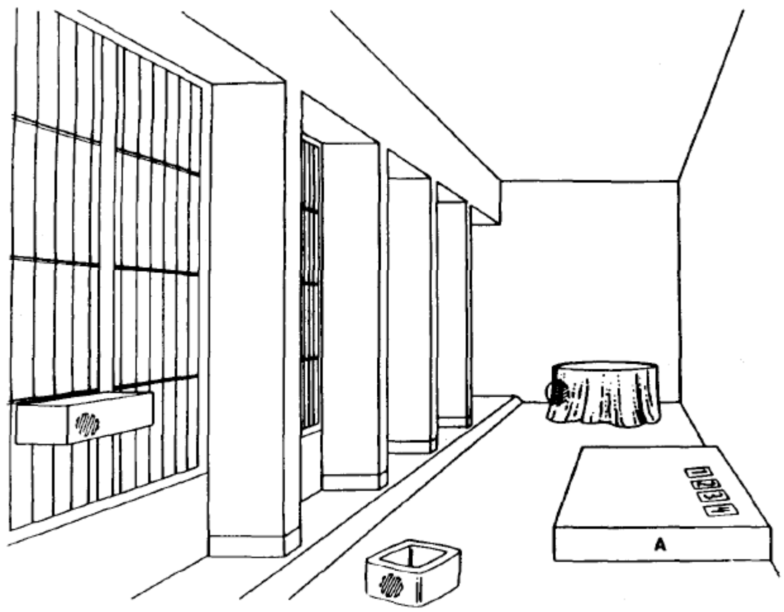
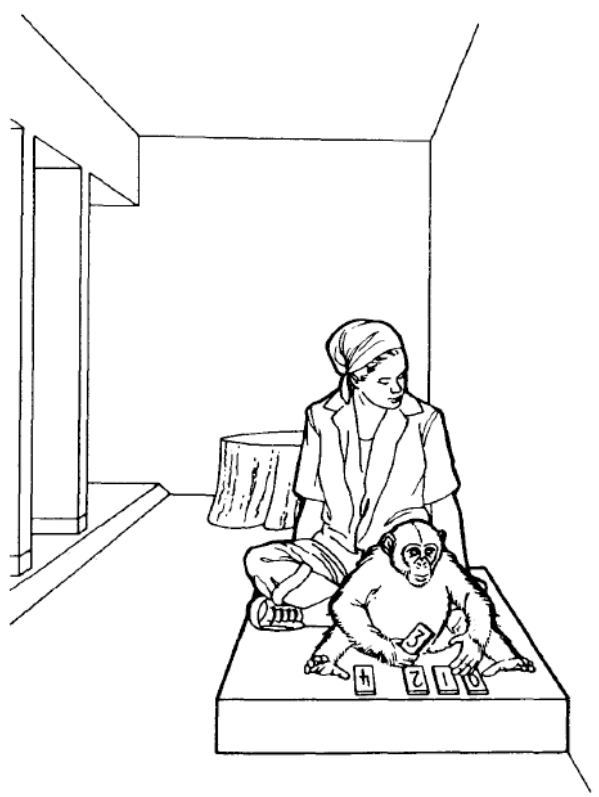


Figure 5. Blind testing format for functional and symbolic counting tasks with the experimenter positioned behind the chimpanzee.



It might also be possible for her to use a strategy known as *counting all,* a simpler counting solution procedure in which the sum is determined by a count of the total number of entities comprising the two addends, in this case, the two separate arrays of oranges (Fuson, 1982). Thus, Sheba would begin her count with the first array and continue the count sequence as she encountered the second array until she had counted all the items to reach a total. In children the differences between the strategies are often overt, because children verbally count-all or count-on or count on their fingers. Thus the emergence of the more efficient counting-on strategies can be more directly measured than in the case of a nonverbal, nonhuman primate. Further study will be necessary to more clearly characterize the nature of the counting strategy that Sheba may be using in the functional counting context.

Experiment 2

Symbolic Counting Task

To test Sheba's ability to use numbers representationally, we replaced the arrays of oranges used in the functional counting task with the Arabic numbers 0-4 on a duplicate set of separate plastic placards identical to her response placards (Figure 6). As in the functional task, two of the three possible sites were baited with a single number during each trial. These included the following number pairs: 1,0; 1, 1; 1,2; 1, 3; 2, 0; 2, 2; and 3, 0. As in the previous task, Sheba was required to visit all three sites during each trial and then to select the Arabic number that was the arithmetic sum of the two numbers. Similar testing procedures were used, with two exceptions. The first six trials of the symbolic counting task were run under the blind conditions described earlier for the functional task, with the experimenter seated behind Sheba during her number selection. The next six trials were run under double-blind conditions in which the numbers were placed at the sites by a second experimenter. Thus, the experimenter seated with Sheba did not know the correct answer for a given trial. Subsequent blind trials were run under conditions as described above for the functional counting task.

Results

Sheba's performance during the first session was significantly above chance, and her performance for blind tests was also significant (Table 5). Trial 1 performance for each of the seven pairs of numbers was also significant (86% correct; see Table 5). Overall, Sheba achieved 81 % correct performance ($p < .001$). Double-blind testing was completed on Day 1, and significant performance was maintained during these and subsequent blind tests (Table 6).

A breakdown of Sheba's performance on different classes of trials is given in Table 6. Although the statistical probability of a correct response in these studies was .25, the deployment of noncounting strategies could have effectively reduced the response options. Thus, Sheba may have simply avoided choosing an answer that was one of the addends. In view of this possibility, Table 6 also gives the more conservative chi-square values with adjusted expected probabilities based only on response options that were not among the addends. As is apparent, performance in all trial classes still remained significant (Table 6). Alternatively, Sheba may have inappropriately applied a simple strategy entailing the selection of the next higher number than the largest addend (e.g., 1 + 2 = 3, select 3; 1 + 3 = 4, select 4). The critical comparison trials for evaluation of this strategy are 2 + 2 and 0 + n (n = 1, 2 or 3), where this strategy would fail. Sheba's performance on these trials, however, far exceeded chance, even with adjusted expected probabilities (16 correct responses in 17 trials or 94%; expected probabilities = .33), $\chi^2(1, N = 17) = 26.2$.

Whereas all of the counting strategies discussed for the functional counting task may also be potential algorithms for use in the symbolic counting situation, successful application of any of the strategies includes an important exception. The arrays in this task were presented as numerical representations, rather than physical entities. Sheba was nevertheless able to provide the correct total for the numbers represented.

Table 4. Functional Counting Task

Stimuli	No. of sessions	No. of trials	No. of correct trials	Probability Correct	Probability Chance	X^2 (1)
1-3	7	82	60	.73	.33	58.32*
1-4	10	89	75	.84	.25	166.42*
Blind	4	38	28	.74	.25	49.83*

*$p < .001$.

General Discussion

Our results suggest that Sheba could effectively sum arrays of objects or Arabic numbers. It is important to note that before this study Sheba received no specific training adding arrays of food, objects, or Arabic numbers, nor had any situation ever arisen in which two arrays or two numbers were presented, either simultaneously or sequentially, for her to sum. Rather, Sheba had extensive work in counting a wide variety of food items with Arabic numbers, and she had a transfer test of counting arrays of novel objects. Her comprehension training involved responding to Arabic numbers and selecting the corresponding array from among three fixed arrays (see Figure 2). She also had extensive experience with the number placards, used as choice stimuli, presented in both ordinal and random sequence during all number tasks. She was never, however, explicitly required to respond to combinations of numbers in any task.

Figure 6. Experimental setting for symbolic counting task.

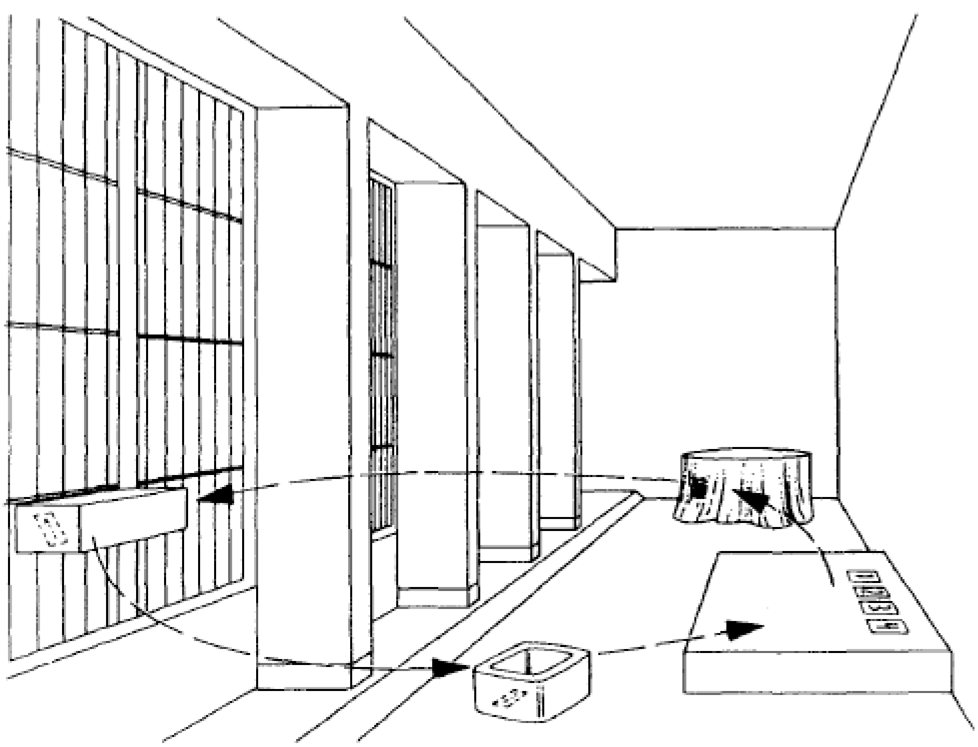


Table 5. Symbolic Counting Task

Stimuli	No. of sessions	No. of trials	No. of correct trials	Probability		χ^2 (1)
				Correct	Chance	
1-4	3	21	16	.76	.25	28.94*
Blind	4	20	17	.85	.25	35.27*

*p < .001

Table 6. Response Distribution for Symbolic Counting Task

Sum	No. of trials	No. of correct trials	% of correct trials	χ^2 (1)	
				.25 probability	Adjusted probability[a]
1	8	7	88	13.5***	8.4**
2	11	10	91	22.1***	14.1***
3	12	10	83	18.8***	5.3*
4	12	11	92	25.0***	9.2**

Note. For Sum, 1 comprised addends 1 + 0; 2 comprised 0 + 2 and 1 + 1; 3 comprised 0 + 3 and 1 + 2; 4 comprised 1 + 3 and 2 + 2.

[a] Expected value adjusted to exclude addends as response options.

*p < .05. **p < .01. *** p <.001.

If comparisons of Sheba's performance are made with preschool children, her responses may represent the first evidence for counting that meet the more stringent criteria proposed by Davis and Perusse (1988) for nonhuman species. Although noncounting processes have been put forth to account for numerical skills demonstrated by other animals, such as number discriminations by birds, numerousness judgments by monkeys, and summation in chimpanzees (Koehler, 1950; Rumbaugh, Savage-Rumbaugh, & Hegel, 1987; Thomas & Chase, 1980), none of these are adequate to account for Sheba's performance during the functional and symbolic counting tasks. Davis and Perusse proposed several criteria that support a counting explanation of numerical competence for Sheba. They defined counting following Stevens (1951), as the process by which one discriminates the absolute numerosity of a set of items. The authors noted that unlike subitizing, the direct apperception of a small set of items (von Glasersfeld, 1982), counting can yield a number along an ordered continuum and can be applied in both logical and descriptive contexts. Their criteria for counting incorporate the principles of cardinality, the use of number tags, and ordinality, the use of these labels in an ordered series; this combination of tag and order must be stable and reliable (Gelman & Gallistel, 1978).

Although Sheba does not apply verbal number labels, she has a set of reliable, ordered tags, in the form of plastic number placards. These were learned in serial order and serve as her output for number tasks. She reliably applies the correct Arabic number label to arrays of familiar and novel foods or objects, demonstrating an appreciation for the special status of the final cardinal number of a count series that designates the entire array (Gelman & Gallistel, 1978). Although it has been assumed that an individual who is able to count must by definition have an understanding of the underlying ordinal nature of numbers, ordinality has been assessed separately in Sheba through a replication of Gillan's (1981) study of transitive inference (Boysen & Berntson, 1988). In addition to learning the ordinal relations among a series of five colored boxes, as in Gillan's study, Sheba also was successful in demonstrating an understanding of the ordinal relation among the numbers 1-5, because she was able to select the larger of a novel pair of numbers (2 and 4) presented during blind testing. These data provide additional support for the proposal that Sheba had some understanding of the ordinal characteristics of the numbers she used.

Evidence for an understanding of ordinality provides additional support for a counting explanation of Sheba's emergent abilities in the functional and symbolic counting tasks. In an earlier study Ferster (1964) trained chimpanzees to associate binary numbers with small arrays, but these animals could not later use the numbers to enumerate items. In contrast, Sheba learned numbers serially, a training procedure that seemed an intuitive way to proceed. In hindsight, serial training was likely one of several critical features of the procedures that contributed to the subsequent flexibility Sheba has demonstrated with numbers in novel contexts. For example, during the modified one-to-one correspondence task (the first phase of numbers training), only gumdrops were used for counting. The same foods were used as Sheba made the transition to Arabic numerals, because other food items created considerable confusion. It was not until her skills with labeling arrays of gumdrops were highly overtrained that Sheba evidenced more flexibility in applying the number labels to arrays of other food types, and then only if they were presented as homogeneous arrays. Combinations of food items again created confusion. Combinations of foods were gradually introduced, until eventually it made no difference in Sheba's performance if arrays were homogeneous or heterogeneous collections of edibles. Thus, Sheba initially related the use of numbers to a very narrow context, that of labeling collections of gumdrops. The applicability of numbers to other items was gradually incorporated into her repertoire. This process may represent, in one sense, a manifestation of Gelman and Gallistel's (1978) abstraction principle, that the how-to-count principles may be applied to any collection of items. Thus, Sheba was able ultimately to apply numbers to heterogeneous arrays of novel objects; through her prior training with different types of foods, she presumably had already come to understand that anything could be counted.

Sheba's numerical skills, particularly as evidenced by the functional and symbolic counting tasks, exceed the criteria for demonstrating counting in a nonhuman species and compare favorably with those specified for young children (Davis & Perusse, 1988; Gelman & Gallistel, 1978). In addition, Sheba also demonstrates motor tagging and partitioning, by pointing, touching or moving items to be counted. A study is currently underway to evaluate the function of such motor tags during counting. For example, do responses that are errors with respect to the number of items in the array reflect the same, though incorrect, number of tags made by Sheba? If the data reveal that motor tags reflect both correct and incorrect responses, it may suggest that these behaviors function to partition items to be counted, similar to the tagging function described for young children (Gelman & Gallistel, 1978). Inconsistent use of tagging, on the other hand, may reflect imitation of the experimenter's behavior during training; such imitation may be acquired through observational learning and may have little or no functional significance.

That Sheba has acquired the ability to count may provide a reasonable explanation for her performance on the functional counting task. It suggests that she completed each novel trial by counting-on (Fuson, 1982; Groen & Resnick, 1977). She may have only had to remember the number of oranges at the first site, move on to the second array, and count up. She then had to remember the cardinal number as she moved on to the number choices located a short distance away to make her selection. Other numerical processes (e.g., subitizing) are inadequate to account for the level of numerical abilities that Sheba demonstrated. Her success with the symbolic counting task provides evidence that she can use numbers representationally. She was able to substitute abstract Arabic numerals for things to be counted and functionally sum them. Without positing that Sheba can count, a parsimonious explanation on the basis of simpler numerical operations is improbable, given her test performance. These findings support the proposal that the chimpanzee is not "peculiarly limited" in its capacity for number conceptualization

(Hayes & Nissen, 1971). Rather, under conditions of appropriate pongid pedagogy, this species may evidence mastery of counting and simple addition not previously demonstrated in a nonhuman animal.

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