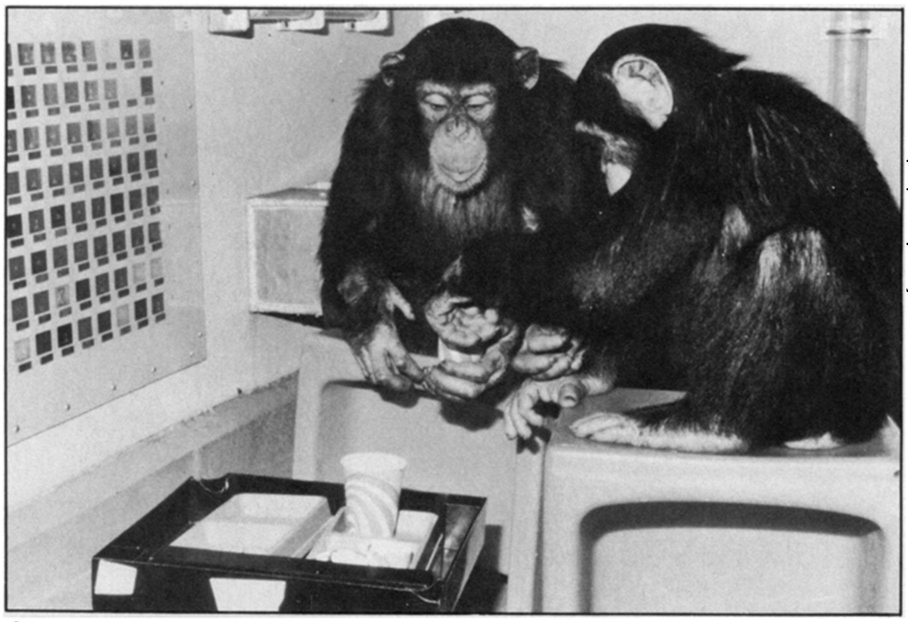
Calculating Apes

When the chips are down, do chimpanzees sum quantities in a simple way linked to the human capacity for counting?

By Bruce Bower



Photos: Elizabeth Rupert/Yerkes/Emory Univ.

Sherman and Austin, who often choose the greater of two paired amounts of chocolate chips, huddle together in a language-training laboratory.

Sherman and Austin, two chimpanzees housed at the Yerkes Regional Primate Research Center in Atlanta, are fond of chocolate. Their sweet tooth, however, has led psychologists at nearby Georgia State University to a distinctly noncaloric conclusion: Sherman and Austin, when presented with two trays of chocolates, can perform a basic type of calculation that may be a precursor of more advanced arithmetic skills used by humans.

"As far as we know, these chimps can't count and do not know numbers," says psychologist Duane M. Rumbaugh. "What's important is that they can somehow combine separate piles of chocolates and, without any reinforcement other than the immediate food reward, choose the pair that nets them the greater amount."

Rumbaugh and colleagues Sue Savage-Rumbaugh and Mark T. Hegel say that this mental operation is a form of "summation." The exact way in which summation works is not clear, but the process involves joining pairs of separate quantities and determining which combination contains the most items. Rumbaugh notes that this is not addition, in which numbers that represent totals of separate sets of items are combined. Addition and other counting operations rely on several abilities, including the tagging of individual items with an ordered series of numbers and knowing that the number assigned to the last member of a counted set also represents the total number of items in the set.

Although research on language abilities of apes and controversy over the findings continue, increasing attention is being focused on whether they can carry out primitive types of calculation that might be linked to the human ability to count.

Sherman and Austin were allowed to choose between two sliding trays placed against a chain link fence enclosing their exercise yard. Each tray contained two food wells with varying amounts of chocolate chips. They could poke a finger through the fence to obtain the chocolate, but once contact with a tray was made, the other tray was immediately drawn out of reach by an experimenter. Each chimp made this type of choice 50 times a day for six days.

In experiments where each food well contained from zero to four chocolate chips, the chimpanzees chose the tray with the greater sum more than 90 percent of the time. For example, a tray with three chips in one well and three chips in the other well was nearly always picked over a tray with four chips in one well and none in the remaining well. When the maximum number of chocolates in a food well was increased to five, Sherman and Austin still chose the tray with the greater sum more than 90 percent of the time.

Their most difficult task was distinguishing between sums of seven and eight. In one such case, a tray with five chips in one well and two chips in the other was placed next to a tray with four chips in each well. The chimps chose the larger of these sums 79 percent of the time.

In the April JOURNAL OF EXPERIMENTAL PSYCHOLOGY: ANIMAL BEHAVIOR PROCESSES, the researchers offer a preliminary explanation of Sherman and Austin's successes. The chimps may first have "subitized" the number of chocolates in each food well. Subitizing — perceiving at a glance up to five items without actually counting them — has been observed in human children and adults. How it works, and its role, if any, in the emergence of counting skills is unclear. Each pair of subitized amounts could have been combined or summated to obtain an estimate of the tray totals, with the summations then compared before a choice was made.

"This is only a model," says Rumbaugh, "but what we've observed with Sherman and Austin seems to be a rudimentary calculation system. They weren't counting, but they got beyond the limits of subitizing."

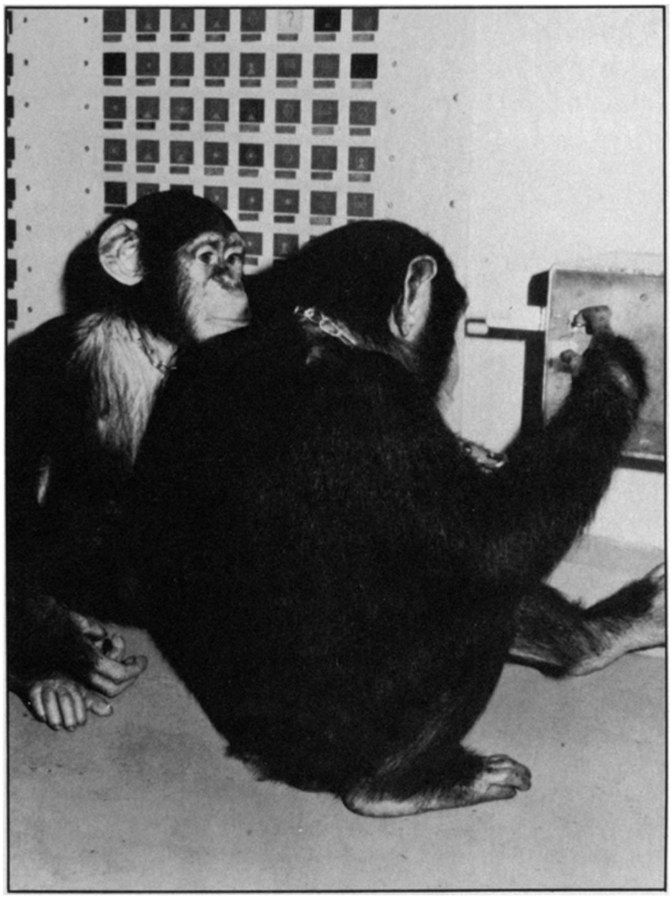
As in ape language studies, however, the significance of the chimps' performance is open to interpretation. Emil W. Menzel of the State University of New York at Stony Brook has only one objection to the model proposed by the Georgia investigators. "Calling the chimps' calculation system 'rudimentary' is putting them down," he says. "This study importantly extends previous work on ape calculation."

In 1960, Menzel reported that chimps quickly learned to distinguish between two colored plaques, one of which resulted in a larger food reward. The apes also learned to rank five opaque plaques according to the amount of food they covered.

Sherman and Austin's chocolate chip choices are an important first step in studying the ability of animals to perform operations on numbers, says Hank Davis of Guelph (Canada) University, but summation remains a murky concept. "Summation may not be a precursor to addition," he maintains. "I'm not convinced that there is a developmental link between the two abilities."

Davis and his colleagues have found that in some situations rats can discriminate between small numbers of events. For example, when three mild shocks are administered during an experimental session, the animals are less apt to press a lever previously associated with food, but they readily learn to resume lever pressing after the third and final shock. When the situation is made more complex by introducing another cue, such as a tone before and after each shock, lever pressing does not rebound after the third shock.

These discriminations are more refined than judgments of "several" or "few," says Davis, but there is no solid evidence that rats, chimps or any other animals can count.



Behind Sherman and Austin is a keyboard with geometric symbols that they were trained to communicate with, but did not use in the chocolate chip "summation" experiment.

Another important study of what may be calculation without counting by an ape was reported in the May 2, 1985, NATURE. Tetsuro Matsuzawa of Kyoto (Japan) University trained a chimp to name 14 objects and 11 colors by choosing among a set of symbols. The chimp then learned to select from a keyboard an Arabic numeral, from one to six, matching the number of objects displayed. When, for example, five blue toothbrushes were shown, the animal pressed keys bearing "5" and symbols for "blue" and "toothbrush."

In this case, says Davis, although the chimp often tagged objects with an appropriate number, it may have formed associations with a "jumble of unrelated number tags" rather than demonstrating knowledge of an ordered series of numbers beginning with "1" and ending with "6."

Unlike Davis and Menzel, David Premack of the University of Pennsylvania in Philadelphia says the chocolate chip experiment with Sherman and Austin does not add up to much. "Summation has to do with quantity judgment, not counting," says Premack, who is also Matsuzawa's postdoctoral supervisor. "The discrimination [that the Georgia researchers] are looking at is so primitive, I'd be surprised if a housefly couldn't do it."

In his own experiments with a language-trained chimp named Sarah, Premack has found that she can match like proportions of objects that do not look alike. For instance, given a choice between a glass of water one-quarter full and three-quarters full, Sarah correctly matches the latter item with three separated quarters off an apple.

Premack suggests that the Georgia researchers must establish whether their chimps can distinguish between, say, three small chocolate chips and two larger chips that take up the same amount of space.

Rumbaugh acknowledges that Sherman and Austin may have combined what they saw as unitary amounts of food, not subitized values, based on estimates of the surface area of each pile of chips. He and his colleagues, however, have found that another language-trained chimp, Lana, appears to be able to count up to three items on a computer screen by using a joystick to control a cursor. Since the size of each item and the volume of quantities can be varied on a computer, the researchers plan to conduct further summation experiments with this technology.

Results so far with Lana are "exciting," says Rumbaugh, and indicate that she is focusing on quantity, not volume. It would be interesting, he adds, to give summation tests to chimps with no language training. Premack holds that, although he believes no important calculation abilities were uncovered in the chocolate chip experiment, language training boosts a chimp's analytical reasoning skills and ability to grasp small numbers and simple fractions (SN:12/5/81, p.363). Davis, on the other hand, says that language is not a requirement to use numbers or judge quantities, since human infants show "remarkable numerical ability." In one study, 7-month-olds showed a preference for looking at an array of objects that matched in number a sequence of sounds presented by experimenters.

"True" counting by children begins at around 4 to 5 years of age, but appears to develop in stages, says Brendan McGonigle of the University of Edinburgh, Scotland. For instance, many 6-year-olds cannot count above 10. At first, the number "1" is often used as an anchor to begin counting; performance falters if counting starts from a higher number. Furthermore, forward counting is mastered before counting backwards.

Summation may be a primitive link in the developmental chain of counting skills, says Rumbaugh. "It may reflect something for which chimpanzees have a need in the wild," he suggests. One possibility is that chimps use a "natural, number-related response" to decide which cluster of berries on a bush should be approached and which branch bears the greater number of buds.

"Studies of this type of behavior in the wild would be fascinating," says Rumbaugh. "But the key question is, when does formal counting become a requisite for these kinds of judgments?" □