

## Reasoning in the Chimpanzee: II. Transitive Inference

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Five experiments investigated transitive inference by chimpanzees. In the initial experiment, three 5-6-yr-old chimpanzees (Sadie, Luvie, and Jessie) received training with pairs of adjacent stimuli from a five-stimulus series. The chimpanzees learned that stimulus E had more food than D, D had more food than C, C more than B, and B more than A (i.e., A-B+, B-C+, C-D+, D-E+). Then, they were tested on the novel nonadjacent pair, BD. Sadie chose D consistently on BD test trials, Jessie chose inconsistently between B and D, and Luvie chose inconsistently in an initial test but chose D consistently in a second test. Coincident with choice of D on BD trials for Sadie and Luvie was highly accurate performance on the adjacent pairs. In Experiment 1B, Sadie received training with five adjacent pairs, A-B+, B-C+, C-D+, D-E+, and E-F+, then during a test with novel nonadjacent pairs, BE and CE, provided further evidence of transitive inference by choosing E consistently. Subsequent experiments examined the effects on nonadjacent pair performance of manipulation of the linear order of stimuli in a series based on relative food values. The presence of a low and a high end point in the series A and F, respectively, was crucial for transitive inference in the BD, BE, and CE pairs (Experiments 2A and 2B). Experiment 3 used a double-blind procedure to demonstrate that elimination of social cues by the trainer did not affect Sadie's test performance on nonadjacent pairs. The present experiments suggest that language is not a necessary condition for transitive inference, because the chimpanzees that demonstrated this type of reasoning have had no language training. In addition, nonintegration theories, which attempt to explain transitive inference by focusing on a subject's experience with individual stimuli or pairs of stimuli, are not sufficient to account for the data. Rather, integration theories, which suggest that a subject integrates information about separate stimuli or pairs into an ordered series, better account for the data.

In a transitive series, A-B-C, if there is some relation between A and B and between B and C, then that relation also holds for A and C. Example transitive relations include magnitude and equality. Therefore, an ex-

ample of a transitive series would be C greater than B, B greater than A. If a subject were given information only about the adjacent terms in a series, e.g., C greater than B and B greater than A, that subject would have to infer the relation between the nonadjacent terms, C greater than A, having received no direct experience with the C-A relation.

Several influential early studies seemed to indicate that humans could not make transitive inferences before the age of 7 yr (e.g., Kendler & Kendler, 1967; Piaget, Inhelder, & Szeminska, 1960). More recently, however, Bryant (1974) and Bryant and Trabasso (1971) showed that the failure of young children in tests of transitive inference was due to memorial, not inferential, deficits: Children younger than seven required

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extensive training on adjacent pairs ( $E > D$ ,  $D > C$ ,  $C > B$ ,  $B > A$ ) to remember them during the test. However, given sufficient training on the adjacent pairs, 4-yr-old children made judgments on a nonadjacent pair that indicated transitive inference ( $D > B$ ). These experiments suggest that transitive inference may be a fundamental type of human reasoning, present even in young children. The experiments reported in the present article investigated whether transitive inference is also a fundamental type of reasoning in another primate species, the chimpanzee. Accordingly, the initial experiment in this investigation studied transitive inference in three young chimpanzees, 5–6 yr old. Subsequent experiments examined certain conditions under which a chimpanzee would and would not make transitive inferences. In addition, for assessment of the importance of language for transitive inference (e.g., Clark, 1969), these experiments used chimpanzees that had not been trained in a language system (see Premack, 1976, for a review of one type of chimpanzee language system).

Because the present experiments used chimpanzees that did not have language, a transitive relation could not be presented symbolically. Rather, the transitive relation, "greater than," was presented concretely by giving the chimpanzees pairs of stimuli in which one stimulus contained a greater amount of food than the other. The subjects received a series of stimuli in which stimulus B had more food than A, C had more than B, D more than C, and E more than D. Note that one way to present such a transitive series to a chimpanzee might involve stimulus E containing 5 pieces of food while D contained only 4; D might contain 4, while C contained 3; C might contain 3 and B 2; B might contain 2 while A contained 1. In the test for transitive inference, the chimpanzee would receive the novel pair D and B. However, in this example, a number of noninferential models could easily account for the choice of D over B. One might assume, for example, that four pieces of food would reinforce the choice response more strongly than would two pieces; thus, on the basis of reinforcement, one would expect a subject given this treatment to choose D.

Because of the above considerations, the present experiments were designed so that on each trial, the stimulus with more food contained one piece of a preferred food whereas the other stimulus contained no food. Consequently, the A stimulus never had any food when it was presented, and the E stimulus always had food when it was presented. The B, C, and D stimuli contained food on one type of trial but not on a second type. Therefore, A and E could be ordered in the series A–B–C–D–E on the basis of the average amount of food each contained, zero and one, respectively. In contrast, B, C, and D could not be ordered in this series solely on the basis of the average amount of food contained in each, but they had to be ordered on the basis of their relations to one another and to A and E. In addition, the stimuli could not be ordered readily by the relations among their physical properties. The stimuli were colored plastic containers, painted orange, white, red, black, or blue.

Following extensive training on each pair of adjacent stimuli in the series, AB, BC, CD, and DE, each chimpanzee received test trials with a nonadjacent pair BD. Since the chimpanzees had no prior experience with the BD pair, choice of D as containing more food than B would indicate that chimpanzees do make transitive inferences.

#### Experiment 1A

The purpose of the first experiment was to evaluate the possibility of transitive inference in young chimpanzees. Three female chimpanzees, 5–6 yr old, received training with four pairs of stimuli from a set of five stimuli, as described above. The stimuli were painted, covered plastic containers. On each trial, one container had food and the other had none. A chimpanzee chose a container on each trial by touching it; she received its contents and was shown the contents of the other container.

The four pairs of stimuli are referred to as A–B+, B–C+, C–D+, D–E+, where – indicates no food and + indicates food in the container and A, B, C, D, and E refer to different colored containers. Subjects were trained until they consistently chose the positive stimulus on each type of trial. Then,

they were tested with choice trials of B and D. On half of these BD test trials, both stimuli contained food, and on the other half, neither stimulus contained food. This procedure was designed to reduce the possibility that a subject would choose D on the first test trial by chance but would continue to choose it on subsequent test trials because that choice was consistently rewarded. In addition to BD test trials, subjects also received trials with the adjacent pairs, AB, BC, CD, and DE, during the test. The adjacent stimuli contained food or no food, as they had during training. Presentation of the adjacent pairs during the test permitted monitoring of the performance on the stimuli that determined the entire series. Previous experiments have shown a relation between correct choice on adjacent pairs and transitive inference on the BD pair (e.g., Bryant, 1974; Bryant & Trabasso, 1971).

### Method

*Subjects and apparatus.* The subjects were three female chimpanzees (*Pan troglodytes*), 5–6 yr old. The chimpanzees, Jessie, Luvie, and Sadie, have been in a variety of experiments on cognitive processes (e.g., Woodruff & Premack, 1979) but have not learned a language system. The subjects were housed in large cages and spent some days outside in a walled .5-acre (.2-hectare) field. Experimental sessions were given in a laboratory room separate from the cages. The stimuli used in the experiment were 11 × 11 × 6.5 cm plastic containers and lids painted red, blue, orange, black, or white. The food placed in the containers were candy, crackers, or, most often, pretzels.

*Procedures.* Experimental sessions consisting of 8–24 choice trials were given by two trainers familiar to the chimpanzees. One trainer set up each trial and presented it to the subjects; the other trainer recorded the data.

One of the trainers brought the chimpanzees, individually, from the home cage or the compound to the laboratory room. The subject was seated on the floor in front of a 39 × 25 × 29 cm cardboard box. The box blocked the chimpanzee's view of the stimuli during the intertrial intervals. A trainer sat opposite the chimpanzee, facing the open side of the box. The experimenter reached into the box and, out of sight of the chimpanzee, put a piece of food into one of the containers, then put lids on that container and on an empty container. The experimenter placed the two containers, side by side, on top of the box in front of the chimpanzee. Care was taken to eliminate the possible use of auditory stimuli as cues for the location of food. On half of the trials, the positive container was placed on the side opposite from where the baiting had occurred; on the other trials, the positive container was placed on the same side as the baiting.

In the first session of Phase 1, the choice response, touching a container, was shaped by presenting the two containers with the lids slightly ajar so that the food inside B was visible. The trainer placed the chimpanzee's hand on the correct, baited container. Each subject required only one to two such trials before beginning to touch one container without prompting, after which the containers were presented with the lids totally covering them. When a subject touched a stimulus, the experimenter opened the container and gave the chimpanzee the food, if any was contained in it, or showed the subject that the container was empty if she had chosen incorrectly. The chimpanzee was also shown the contents of the other container: The trainer removed the lid and allowed the subject to look into the container but not to take the food on those trials in which the chimpanzee had chosen the other, empty container. Then, both stimuli were removed to prepare for the next trial.

During the initial phase of the experiment, the same two stimuli, A and B, were presented on each trial. On these trials, B contained food and A contained no food (A–B+). Right-left position of the containers was varied irregularly throughout the experiment. This phase continued for each animal until she consistently chose B.<sup>1</sup> Then, in the next phase, trials consisted of a choice between B, which now contained no food, and C, which contained food (B–C+). After a subject consistently chose C on these trials, she received A–B+ and B–C+ trials intermixed within a session in irregular order. In the next phase, the chimpanzees received trials in which D contained food and C contained none (C–D+). After an animal reached criterion on this trial type, she was given A–B+, B–C+, and C–D+ trials intermixed in an irregular order within the same session. In the final two training phases, the E stimulus was introduced in a corresponding manner: sessions with D–E+ until criterion was reached, followed by sessions in which all four trial types, A–B+, B–C+, C–D+, D–E+, were intermixed in an irregular order. Each subject had to reach criterion on each of the four trial types in this final phase.

Phase 1 lasted for 3 sessions for Sadie, 5 sessions for Luvie, and 4 sessions for Jessie. In Phase 2, Sadie reached criterion after 4 sessions, Luvie after 2 sessions, and Jessie after 3 sessions; Sadie completed Phase 3 in 5 sessions, Luvie in 2 sessions, and Jessie in 4 sessions. All three subjects reached criterion after 1 session in Phase 4; Phase 5 required 3 sessions for Sadie, 3 for Luvie, and 5 for Jessie; in Phase 6, Sadie reached criterion after 6 sessions, Luvie after 1 session, and Jessie

<sup>1</sup> The criterion used throughout Experiment 1A and all subsequent experiments was based on the binomial test. The criterion was applied only on a subject's whole-session performance, that is, was applied at the end of a session to the trials in that entire session or that session combined with preceding entire session(s). Thus, if a session ended and a subject had chosen correctly on 6 of 6 consecutive trials, 7 of 7, 7 of 8, 8 of 9, 9 of 10, and so on (see Hays, 1973), she had reached criterion and was moved to the next phase of the experiment. In phases of the experiment that had two or more pairs, criterion had to be reached at the same time on all pairs before she was moved to the next phase.

after 2 sessions. The final training phase lasted for 8 sessions for Sadie, 18 sessions for Luvie, and 7 sessions for Jessie. The interval between sessions was 1-3 days. Because a subject reached criterion independently of other subjects, the three subjects differed somewhat in the number of trials in each phase. However, these differences were not substantial until the final phase in which all four types of trials were given. In that final phase, Jessie reached criterion in 84 total trials, Sadie in 100 total trials, and Luvie in 292 total trials.

Each chimpanzee had differently colored containers as A, B, C, D, and E. In addition, the colors were assigned to the sequence so that there was no obvious natural order to the series of colors. Sadie had orange, white, red, black, and blue as A through E, respectively; Jessie had orange, black, blue, white, and red, respectively; Luvie had red, black, orange, white, and blue, respectively. Note that all three subjects had black or white as B and D. This was to reduce the possibility of different amounts of stimulus generalization between the other stimuli and B and D on the basis of color.

*Test.* Each subject received three test sessions after reaching criterion on all four types of trials in the final training phase. The first test session was given on the day following completion of training. Test sessions were like training sessions except as noted. Each test session consisted of 16 trials—3 each of A-B+, B-C+, C-D+, D-E+ trials and 4 test trials in which the subject had to choose between B and D. On two of the BD test trials, both B and D contained food; on the other two BD trials of each session, neither contained food. A naive trainer, who did not know the stimulus order, presented the stimuli to the animals during the third session.

Following the test, Luvie received additional training on adjacent pairs and a second test. On the day after completion of the first test, Luvie received one training session with four trials each of A-B+, B-C+, C-D+, and D-E+. During each of the next 3 days, she was given test sessions with two trials each of A-B+, B-C+, C-D+, and D-E+ and four BD test trials. The procedure was like that in the first test.

## Results and Discussion

*Training.* All three chimpanzees reached criterion in each of the seven training phases. The total number of trials and the number correct on each of the four types of trials over all phases of training are shown for each animal in Table 1. The three subjects chose the container with food on a high percentage of every type of trial, with the exception of Sadie who chose E on slightly fewer than 50% of the D-E+ trials. She chose E on only 9 of the first 56 D-E+ trials but chose it on 36 of the final 37 D-E+ trials.

During the final training phase, subjects chose correctly on all four types of trials when the trials were intermixed within a session. Jessie chose the container with food on 81%, 71%, 71%, and 90% of A-B+, B-C+,

Table 1

*Number of Correct Choices out of Total Trials of Each of Four Trial Types in Training in Experiment 1A*

Subject	Trial type			
	A-B+	B-C+	C-D+	D-E+
Jessie	103/122	74/109	62/74	42/54
Luvie	105/128	89/103	63/93	66/89
Sadie	73/95	81/111	33/45	45/93

C-D+, and D-E+ trials, respectively. The corresponding performance for Luvie was 96%, 84%, 62%, and 73%, correct and for Sadie was 100%, 64%, 64%, and 96% correct. In addition, the animals' performances differed during this final training phase in ways not reflected in overall percentage correct. Jessie chose correctly at a moderate level of accuracy on all trial types throughout the final phase. Her performance in the first three sessions was not markedly different from that in the last three sessions. In contrast, Luvie's performance was erratic. She would choose correctly on all trial types for two or three consecutive sessions, then would choose incorrectly on one or more trial types for the next two or three sessions. Sadie began the final training phase by choosing correctly on the A-B+ and D-E+ pairs but incorrectly on B-C+ and C-D+ pairs. Her performance gradually improved on B-C+ and C-D+, and by the end of training, she chose correctly on all four types of trials.

*Test.* The data for the test for each chimpanzee are shown in Table 2. The table shows performance on A-B+, B-C+, C-D+, and D-E+ (adjacent pairs) trials given during the test and performance on BD test trials. On the adjacent pairs, overall, Jessie chose correctly on 69%, Luvie on 72%, and Sadie on 89% ( $ps < .05$ ,  $< .01$ , and  $< .001$ , respectively, binomial test).

The data of most interest from the test were the number of choices of D on BD trials. Sadie chose D on all 12 trials ( $p < .001$ , binomial test), whereas Luvie chose D on 5/12 test trials, and Jessie chose it on 7/12 test trials (both  $ps > .05$ ).

One notable feature of the test data is that Sadie consistently chose D on BD trials and was also highly accurate on the adjacent

Table 2  
*Number of Correct Choices out of Total  
 Number of Adjacent Pair Trials and Number  
 of Choices of D on BD Trials in Experiment  
 1A Test*

Subject	Adjacent pairs				BD
	A-B+	B-C+	C-D+	D-E+	
Jessie	9/9**	3/8	6/9	7/10	7/12
Luvie	9/9**	5/9	7/9	5/9	5/12
Sadie	8/9*	9/9**	6/9	9/9**	12/12***

Note. Data for Luvie are from her first test.

\*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

pairs in the test. In contrast, the other chimpanzees chose D less often and were less accurate on the adjacent pairs. Because of this possible correspondence between performance on adjacent pairs and that on BD trials, Luvie, whose choice on adjacent pairs during training had been erratic, received a refresher training session and a second test. The purpose of this procedure was to try to test Luvie when she was performing at a high level of accuracy on adjacent pairs, and thereby to investigate further the relation between adjacent pair performance and choice of D on the nonadjacent pair, BD. Luvie chose more accurately on refresher trials; 14 of 16 correct. Luvie's choice on adjacent pairs during the test was also more accurate: She chose correctly on 88% of the trials (5/6 A-B+, 4/6 B-C+, 6/6 C-D+, and 6/6 D-E+). Coincident with her improved performance on adjacent pairs, she chose D on 10 of 12 BD test trials ( $p < .05$ , binomial test).

The results from the present experiment agree with the previous observations in experiments with children, that performance on adjacent pairs from a series is related to performance on nonadjacent pairs (see Bryant, 1974; Bryant & Trabasso, 1971). Combination of the data from Sadie's test and Luvie's second test shows that they chose D on 22 of 24 trials (92%) and chose correctly on 53 of 60 adjacent trials given during the test (88%). In contrast, combination of the data from Jessie's test and Luvie's first test shows that they chose D on 12 of 24 BD trials (50%) and chose correctly on 51 of 72 adjacent trials during the test

(71%). Thus, Sadie and Luvie in her second test chose D significantly more often on BD trials and were correct significantly more often on adjacent pairs than Jessie or Luvie in her first test ( $z_s = 2.86$  and  $2.24$ , respectively, both  $ps < .05$ ).

There are numerous possible explanations of Sadie's and Luvie's choice of D on novel, nonadjacent BD trials. Many of these explanations center around the food paired with choice of B and D during the experiment. One simple explanation, for example, is that choice on any trial is a function of the number of rewards and nonrewards paired with a stimulus during training. Therefore, if rewards increase the likelihood of choice of a stimulus and nonreward decreases that likelihood, then the chimpanzees might have chosen D on BD trials simply because of pairings of B and D with food reward and nonreward (e.g., Spence, 1936). The number of rewarded and nonrewarded choices of B and D can be determined by examination of Table 1. Rewarded choices of B and D are listed as number of correct choices on A-B+ and C-D+ trials, respectively. Nonrewarded choices of B and D are the number of incorrect choices on B-C+ and D-E+ trials, respectively. Since Sadie chose D over B most consistently during the test, her data are of primary interest. Sadie was rewarded for choice of B on 73 trials during training but was not rewarded for choice of B on 30 trials. Thus, B was paired with reward considerably more often than not. Sadie was rewarded for choice of D on 33 trials during training but was not rewarded for choice of D on 48 trials. Thus D was paired with reward considerably less often than with nonreward. Therefore, according to an explanation based simply on the number of rewards and nonrewards paired with B and D, Sadie should have chosen B over D. Since she chose D over B, this simple account cannot explain the basic finding of Experiment 1A.

A second simple explanation of Sadie's and Luvie's choice of D over B on test trials centers around the recency of reward. During training, the pairs were added in the order A-B+, B-C+, C-D+, and D-E+. Thus, the preferential reward of choice of D on C-D+ trials was temporally closer to

the test than was the preferential reward of choice of B on A-B+ trials. Therefore, the chimpanzee's choice of D might have reflected this recency of preferential reward. However, several aspects of the present procedure argue against such an explanation. First, not only was preferential reward of choice of D temporally closer to the test than was reward of B, but nonreward of D on D-E+ trials was temporally closer to the test than was nonreward of B on B-C+ trials. In fact, nonreward of D was more recent than was reward of D. The recency of nonreward might be expected to reduce partially any effects of reward recency. A second aspect of the procedure is that the phase immediately preceding the test involved all four trial types, A-B+, B-C+, C-D+, and D-E+, presented in an irregular order within a session. This phase consisted of 8 sessions for Sadie, 18 for Luvie, and 7 for Jessie. Thus, no subject received exclusive reward or nonreward of D (or any other stimulus) for many sessions prior to testing. It is likely that the lengthy final training phase reduced any reward recency effects. Third, Sadie received 14 sessions in Phases 6 and 7 between the preferential reward of D in Phase 5 and the test, whereas Jessie received only 9 sessions between the preferential reward of D in Phase 5 and the test. An explanation of the test performance based on recency of reward of D to the test would not predict the observed data, greater choice of D by Sadie than by Jessie during the test. Finally, Luvie did not choose D significantly often in the first test but did in a second test. The session between the two tests included all four trial types in an irregular order. Thus, the first test was temporally closer to the training phase in which choice of D was preferentially rewarded than was the second test. Although these four procedural aspects do not conclusively rule out a reward-recency explanation of Sadie's and Luvie's choice of D during the test, they fail to provide any support for such an explanation.

A third type of explanation of Sadie's and Luvie's choice on nonadjacent test trials focuses on the rewards given on the test trials. It might be suggested that Sadie chose at random on the first BD trial but was adven-

titiously rewarded for choice of D since both B and D were baited. Consequently, her likelihood of choosing D on the second BD trial would probably be increased. Because neither B nor D was baited on the second trial, her choice of D was not rewarded on the second trial. However, the nonreward may not have totally counteracted the previous effects of reward, and choice of D may have continued to be more probable than choice of B (e.g., Spence, 1936). However, Jessie, like Sadie, chose D on the first four trials but chose B on the next four trials. An adventitious reward explanation would have to account for Jessie's switch from D to B and her overall failure to choose D significantly often despite the same initial reward of choice of D as Sadie received.

The test performance by Sadie and Luvie in Experiment 1A could be taken as evidence for transitive inference by chimpanzees. However, as the above discussion of alternative explanations suggests, the data do not uniquely support such a hypothesis. The remaining experiments were designed to provide additional and stronger evidence that chimpanzees can make transitive inferences.

#### Experiment 1B

An additional simple explanation of Sadie's substantial choice of D on BD trials during the test in Experiment 1A is that Sadie had an unlearned preference for the color of the D stimulus, black. To examine this hypothesis, I gave Sadie training like that in Experiment 1A, but with an additional adjacent pair, E-F+. Thus, during training, she was given A-B+, B-C+, C-D+, D-E+, and E-F+. Then, in a subsequent test, she was given the nonadjacent test pairs BE and CE. Testing Sadie on additional stimuli reduced the likelihood that she was tested only on a highly preferred colored stimulus.

#### Method

The subject was Sadie, one of the chimpanzees from Experiment 1A. The stimuli and procedures were like those of Experiment 1A except as noted.

Following the test in Experiment 1A Sadie received one training session in which a yellow container had food in it and a blue container had none (E-F+). Then, she received 11 daily sessions with the four types of

trials from Experiment 1A intermixed with E-F+ trials in an irregular order. Four trials of each type were given in Sessions 1-5 and 11; 12 E-F+ trials and 2 of each other type of trial were given in Sessions 6 and 7; and 8 E-F+ trials and 3 trials of each other type were given in Sessions 8-10. After Sadie reached criterion on each pair, she received four test sessions consisting of two trials each of the five adjacent pairs and four trials each of two novel, nonadjacent pairs: BE and CE. On all BE and CE test trials, food was in both containers. A trainer, who did not know the series order, presented the stimuli to Sadie in Test Session 2.

### Results and Discussion

**Training.** Sadie chose the F container on seven of eight trials in the session with only E-F+ trials. During the sessions with all five trial types, she chose correctly on 86% of A-B+, 68% of B-C+, 73% of C-D+, 89% of D-E+, and 64% of E-F+ trials.

**Test.** The results of the test are shown in Table 3. Sadie again chose correctly on a high percentage of adjacent trials during the test (88%;  $p < .001$ , binomial test). In addition, she chose E on 10 of 12 BE and 10 of 12 CE test trials (both  $ps < .05$ , binomial test). Combination of Sadie's test results from Experiments 1A and 1B shows that she chose D or E on 32 of 36 nonadjacent trials ( $p < .001$ , binomial test).

Sadie consistently chose D over B, E over B, and E over C in the present experiments. It is unlikely that Sadie's choice of both D and E in these tests was governed by unlearned color preferences. Rather, her choice of those stimuli was more likely due to some experiential factor(s).

One noteworthy aspect of the data of Experiment 1B is that Sadie chose E over B on 10 of 12 test trials, even though B was chosen in 11 of 16 adjacent trials in the test (on 8 of 8 A-B+ and 3 of 8 B-C+ trials), whereas E was chosen on only 6 of 16 adjacent trials

in the test (on 6 of 8 D-E+ and 0 of 8 E-F+ trials). These adjacent trial data suggest that Sadie did not have an especially strong tendency to choose E whenever it appeared or to avoid choice of B. Despite this, she chose E over B when they were given in the same pair. In addition, as in Experiment 1A, the present test results cannot be accounted for by the total number of rewards and nonrewards paired with the individual stimuli. During all her training prior to the test in Experiment 1B, Sadie was rewarded for choosing B on 113 trials and not rewarded for choosing B on 42 trials, rewarded for choosing C on 115 trials and not rewarded for choosing C on 25 trials, and rewarded for choosing E on 90 trials and not rewarded for choosing E on 37 trials. Thus, on the basis of the total number of rewards and nonrewards paired with these stimuli, Sadie would not be expected to choose E over B and E over C consistently. Since she chose E significantly often, experiential factors other than merely the number of rewards and nonrewards must have been important. The data from Experiment 1B do not provide additional information that would be especially helpful in evaluating the other reward-based explanations discussed in Experiment 1A, reward recency and reward during the test. Experiments 2A and 2B present data relevant to those accounts.

### Experiment 2A

In Experiments 1A and 1B, Sadie received training with pairs of adjacent stimuli from a series ordered in terms of relative amounts of food contained in each stimulus. In these experiments, Sadie was given trials in which F had more food than E, E had more than D, D more than C, C more than B, and B

Table 3  
*Number of Correct Choices out of Total Trials on Adjacent Pair Trials and Number of Choices of E on Nonadjacent Pair Trials in Experiment 1B Test*

Subject	Adjacent pairs					Nonadjacent pairs	
	A-B+	B-C+	C-D+	D-E+	E-F+	BE	CE
Sadie	8/8**	5/8	8/8**	6/8	8/8**	10/12*	10/12*

\*  $p < .05$ . \*\*  $p < .01$ .

more than A. When tested on various non-adjacent pairs from the series BD, BE, and CE, Sadie chose D or E. Thus, her choice on these novel test trials was consistent with a hypothesis that she had integrated the separate stimuli into an ordered series on the basis of her experience with adjacent pairs. Such a hypothesis would also suggest that manipulation of the series order should modify Sadie's choice on nonadjacent test trials.

One feature of the series order used in Experiments 1A and 1B was that it was a linear order, that is, the stimuli could be ordered on a linear scale of increasing relative food value, with A at the low end of the scale and F at the high end of the scale (in Experiment 1B). In Experiment 2A, the series order was modified to eliminate the low and high end points of the series: Sadie received trials with the adjacent pairs A-B+, B-C+, C-D+, D-E+, and E-F+, as described in Experiment 1B and, in addition, received F-A+ trials in which the A stimulus contained food and the F stimulus contained none. Thus, A was no longer the low point on a unidimensional scale of food value, nor was F the high point. Rather, the series no longer had end points.

Following extensive training on the six pairs of stimuli, Sadie was tested with the nonadjacent test pairs, BD, BE, and CE, as in Experiments 1A and 1B. One noteworthy feature of the design of Experiment 2A is that the manipulation of the order of the series by presentation of F-A+ trials did not involve a change in procedure from the previous experiments for the test stimuli, B, C, D, and E. Thus, any change in test performance in Experiment 2A from Experiments 1A and 1B cannot be attributed to direct manipulation of the test stimuli but must be related to modification of the values of A and F.

### Method

Procedures were like those of Experiment 1A except as noted. After completion of Experiment 1B, Sadie received five sessions in which all trials had the orange container, A, with food and the yellow container, F, with no food (F-A+). After she reached criterion on this pair, she was given 15 sessions with all six trial types, A-B+, B-C+, C-D+, D-E+, E-F+, and F-A+, presented in an irregular order. The stimuli A, B, C, D, E, and F were those used in previous experiments. After

Sadie reached criterion on each type of trial, she received a test similar to those given in Experiments 1A and 1B. During each of the four test sessions, Sadie was given two trials each of A-B+, B-C+, C-D+, D-E+, E-F+, and F-A+. As in previous tests, the + container had food, and the - container had no food. In addition, in every test session, she received three trials each of three types of test trials, BD, BE, and CE. On 6 of the 12 total BD test trials, both containers had food, and on the other 6 BD trials neither container had food. On all BE and CE test trials, both containers had food. Therefore, the baiting on test trials was identical to that in Experiments 1A and 1B. As in those previous experiments, a trainer who did not know the series order presented the stimuli to Sadie in Session 2.

### Results and Discussion

*Training.* Sadie was slow to reach criterion in sessions with only F-A+ trials and in sessions with all six types of trials intermixed. In F-A+ sessions, she chose A on 0/8, 3/12, 6/12, 9/12, and 10/12 trials, respectively; Sadie chose F on the first 12 F-A+ trials ( $p < .05$ , Grant's runs test; Grant, 1947). During the initial part of training with all six pairs, F-A+ training affected performance on the A-B+ and E-F+ adjacent pairs. During the four sessions of the test phase of Experiment 1B, her last prior experience with the adjacent pairs, she had chosen correctly on 8/8 A-B+, 5/8 B-C+, 8/8 C-D+, 6/8 D-E+, and 8/8 E-F+ trials. In contrast, during the first four sessions with all six adjacent pairs in the present experiment, she chose correctly on 5/12 A-B+, 12/12 B-C+, 9/12 C-D+, 8/12 D-C+, and 7/12 E-F+ trials as well as 9/12 F-A+ trials. Despite this initial effect on the adjacent trials, Sadie reached criterion after 15 sessions with six trial types intermixed. Throughout these 15 sessions, she chose correctly on 70% of the A-B+ trials, 100% of B-C+, 64% of C-D+, 66% of D-E+, 74% of E-F+, and 82% of F-A+ trials.

*Test.* As in Experiments 1A and 1B in which she chose correctly in the test on 89% and 88% of the adjacent trials, respectively, Sadie chose correctly on a high percentage, 90%, of the A-B+, B-C+, C-D+, D-E+, E-F+, and F-A+ trials given during the test. She chose the container with food on 7/8, 5/8, 7/8, 8/8, 8/8, and 8/8 trials, respectively. Performance on these types of trials did not differ in Experiment 2A from

that in Experiments 1A and 1B combined ( $z = .54, p > .05$ ). In contrast, Sadie's performance on BD, BE, CE test trials was very different in Experiment 2A from that in Experiments 1A and 1B. In the present test, she chose D on 3 of 12 BD trials, E on 8 of 12 BE trials, and E on 7 of 12 CE trials. Combining the three types of test trials with nonadjacent pairs, Sadie chose D or E on only 18 of 36 trials ( $p > .05$ , binomial test). Thus, Sadie chose D and E less often on nonadjacent trials in Experiment 2A than in Experiments 1A and 1B ( $z = 3.33, p < .001$ ).

Comparison of the data from the test in Experiment 2A with those from the tests in Experiment 1 shows that after substantial training, presentation of F-A+ trials no longer disrupted performance on adjacent trials but did disrupt performance on nonadjacent trials, resulting in inconsistent choice on BD, BE, and CE trials. Although previous results (e.g., Bryant & Trabasso, 1971; Experiment 1 of this study) have indicated that accurate performance on adjacent pairs may be a necessary condition for choice of D and E on nonadjacent pairs, the present experiment suggests that it is not a sufficient condition. These findings suggest that there are two necessary conditions for choice of D on BD trials and E on CE and BE trials with the present procedures: (a) accurate performance on adjacent pairs and (b) the stimuli from a series must be orderable on some unidimensional scale. When that linear order is violated by elimination of the low and high end points of the scale, consistent choice on nonadjacent trials is likewise eliminated. However, an alternative explanation of the data must be acknowledged. It may be that addition of a sixth type of trial in Experiment 2A exceeded Sadie's cognitive capacities and that this excess, rather than the modification of the linear order of the stimuli, disrupted test performance. Experiment 2B examined this possibility.

### Experiment 2B

In Experiments 1A and 1B, in which Sadie was trained on four and five pairs of adjacent stimuli from an ordered series, she also chose D and E on nonadjacent test trials, BD, BE,

and CE. In contrast, in Experiment 2A in which she received training with an added sixth pair, F-A+, she no longer chose D and E consistently on test trials. Was the disruption of choice on nonadjacent trials due simply to the addition of a sixth pair in training, or was it due to a feature of the specific pair added, e.g., the modification in the linear order of the series of stimuli produced by that pair? For distinguishing between these two possibilities, Sadie received training with six pairs of stimuli, similar to training in Experiment 2A but not violating the linear order of the stimuli. The pairs were A-B+, B-C+, C-D+, D-E+, E-F+, and A-F+. Thus, the only difference between Experiments 2A and 2B was on AF trials. In Experiment 2A, F-A+ trials eliminated the linear order of the values of the stimuli. In Experiment 2B, A-F+ training, in conjunction with training on the adjacent pairs, reinstated the linear order of values of the stimuli with A as the low end point and F as the high end point. If choice of D and E on nonadjacent trials is related to the linear order, then Sadie should again choose those stimuli in Experiment 2B.

### Method

Procedures were like those of Experiment 1A except as noted. Following the test in Experiment 2A, Sadie was given three sessions in which all trials had the yellow container with food in it and the orange container with no food (A-F+). After she reached criterion in this phase, Sadie was given seven sessions with the six types of adjacent pairs, A-B+, B-C+, C-D+, D-E+, E-F+, and A-F+, intermixed. Following criterion in that phase, she received four test sessions like those in Experiment 2A, with the exception that A-F+ trials were given instead of F-A+. In Sessions 1 and 4, Sadie was presented the stimuli by a trainer who did not know the series order.

### Results and Discussion

*Training.* During the first session of A-F+ training, Sadie chose F on 4 of 8 trials but chose F on 8 of 12 and 9 of 12 trials in Sessions 2 and 3, respectively. In the next phase, she reached criterion in all six trial types after seven sessions with all trial types intermixed. Her overall performance during these sessions with all trial types was 71% correct on A-B+, 86% on B-C+, 90% on

C-D+, 81% on D-E+, 90% on E-F+, and 100% on A-F+.

*Test.* As in all previous experiments, Sadie chose correctly on adjacent trials during the test. She chose the container with food on 94% of these (and A-F+) trials: 7/8 on A-B+, 6/8 on B-C+, and 8/8 on all other trial types. However, in contrast to Experiment 2A, but in agreement with Experiments 1A and 1B, she chose D and E on nonadjacent test trials. She chose D on 8 of 12 BD trials, E on 11 of 12 BE trials, and E on 11 of 12 CE trials. Therefore, she chose D or E on 30 of 36 test trials ( $p < .01$ , binomial test); this was significantly greater than choice of D and E in Experiment 2A ( $z = 2.75$ ,  $p < .01$ ) but did not differ from the combined results of Experiments 1A and 1B ( $z = .34$ ,  $p > .05$ ).

The test data from Experiments 1A and 1B combined, Experiment 2A, and Experiment 2B are presented in Table 4 for comparison. It is clear that there was little variation in performance on adjacent trials given during the tests. This is to be expected since Sadie had to choose correctly on each of these types of trials during training before she was tested. In contrast to the stable performance on adjacent pairs, there was a substantial effect on choice on nonadjacent pairs as the values of A and F were varied. When A had the lowest value in the series of stimuli and F the highest value, D and E were chosen on BD, BE, and CE trials (Experiments 1A, 1B, and 2B). When A and F did not serve as the low and high end points in the series of values but were linked by trials in which there was more food in A than in F, choice of D and E on nonadjacent trials fell to chance (Experiment 2A). This manipulation of the values of A and F was of special interest since that procedure did not involve

the test stimuli, B, C, D, and E. These data, taken as a whole, indicate that choice of D and E on nonadjacent test trials was dependent on the series of stimuli having low and high end points.

The results of Experiments 2A and 2B address several explanations of the test data of Experiment 1A and 1B. First, it is unlikely that an unlearned color preference determined Sadie's choice of D and E in those earlier experiments, failed to influence her in Experiment 2A, but again determined her choice in Experiment 2B. Second, an explanation that proposes that choice of D and E on nonadjacent test trials was due to the temporal proximity between unique pairing of those stimuli with food reward and the test does not seem to be sufficient to account for the present data. Unique pairing of reward with D and E was temporally closer to the test in Experiment 2A than to the test in Experiment 2B. However, Sadie consistently chose D and E on nonadjacent test pairs in Experiment 2B, but not Experiment 2A. Thus, the temporal proximity of unique reward of D and E and the test appears not to be a determinant of choice on nonadjacent trials.

In addition, the findings of the present experiments are difficult to explain in terms of adventitious reward of the choice of a stimulus on nonadjacent test trials. Such an explanation would predict that for Sadie, at the start of the test in Experiment 2A, the probability of choice of D should have been higher than the probability of choice of B on the basis of rewards paired with choice of D in Experiment 1A. Indeed, Sadie chose D on the first BD test trial in Experiment 2A and received food for that choice. However, she chose D on only 2 of the next 11

Table 4  
*Number of Correct Choices out of Total Number of Adjacent Pair Trials and Number of Choices of D on BD Trials and of E on BE and CE Trials by Sadie in Several Experiments*

Experiment	Adjacent pairs							Nonadjacent pairs		
	A-B+	B-C+	C-D+	D-E+	E-F+	F-A+	A-F+	BD	BE	CE
1A and 1B	16/17	14/17	14/17	15/17	8/8	—	—	12/12	10/12	10/12
2A	7/8	5/8	7/8	8/8	8/8	8/8	—	3/12	8/12	7/12
2B	7/8	6/8	8/8	8/8	8/8	—	8/8	8/12	11/12	11/12

trials in the test. The failure to choose D in Experiment 2A is counter to the expectations of an adventitious reward interpretation of the results of nonadjacent test trials, as are the failures to choose E consistently on BE and CE trials. In Experiment 2A, Sadie chose B on 13 of 24 BD and BE trials and received food on 9 of those 13 trials and chose C on 5 of 12 CE trials and received food on all 5 trials. According to an adventitious reward hypothesis, these pairings of reward with choice of B and C would increase the probability that those stimuli would be chosen on subsequent BD, BE, and CE trials. However, when Sadie next received these three nonadjacent trial types in Experiment 2B, her choice of B and C decreased, as she returned to choosing D and E. Thus, taken as a whole, the data from Experiments 2A and 2B are difficult to explain in terms of adventitious reward of stimulus choice during nonadjacent test trials.

The present data fail to support a variety of explanations of Sadie's choice on nonadjacent trials that are based solely on food reward paired with individual stimuli. Rather, they suggest an interpretation based on the order of the entire series as an important determinant of her choice on nonadjacent trials. Certainly, the data in Experiments 2A and 2B demonstrate that her choice was sensitive to manipulation of order.

### Experiment 3

An additional noninferential explanation of the data from Experiments 1 and 2 is that social cues from a trainer knowledgeable about the series order may have been available to the chimpanzees on test trials. Social cuing was controlled on at least one test session in each of the previous experiments because stimulus presentation was by a trainer who was not knowledgeable about the series order or which stimulus choices would indicate transitive inference. However, the present experiment implemented an even more stringent, double-blind control for social cues in which only an unknowledgeable experimenter was visible to the chimpanzee during the test. Consequently, that experi-

menter could not have provided social cues about the choice of the correct stimulus.

### Method

Following the test in Experiment 2B, Sadie received two test sessions similar to those described for Experiment 2B except as noted. Each test session had two trials each of the adjacent pairs, A-B+, B-C+, C-D+, D-E+, and E-F+, and three trials each of the nonadjacent pairs, BD, BE, and CE. As in previous tests, both containers were baited on all BE and CE trials; both containers were baited on three BD trials, and neither was baited on three BD trials.

One procedural difference between this test and the previous tests was that the person who set up the trials could not be seen by the subject or by the experimenter who presented the stimuli to the subject. The subject was seated in front of the experimenter; the other person was blocked from their view by a plastic curtain. The hidden person set up a trial and passed the stimuli through the curtain to the experimenter. The experimenter did not know the series order or the "correct" stimulus on either adjacent or nonadjacent trials. Although the experimenter had served as the unknowledgeable experimenter in previous experiments, he had not learned which container was baited on adjacent pairs, had not inferred the series order, and could not choose accurately on adjacent or nonadjacent trials. The experimenter placed the stimuli on a box in front of Sadie, and she indicated her choice by touching the container. She received the contents of the chosen container and was shown the contents of the other, as in previous experiments. The experimenter told the hidden person what stimulus Sadie had chosen and that person recorded the data. He provided no feedback to either the experimenter or Sadie. This procedure was repeated for every trial during the two-session test.

### Results and Discussion

Sadie's accuracy on adjacent trials during the double-blind test was similar to that of previous experiments. She chose correctly on 90% of the trials: 4/4 A-B+, 4/4 B-C+, 3/4 C-D+, 4/4 D-E+, and 3/4 E-F+. In addition, she chose D or E on 17 of 18 nonadjacent trials ( $p < .01$ , binomial test). She chose D on 5/6 BD trials and E on 6/6 BE trials and 6/6 CE trials. Thus, Sadie's choice behavior in the present experiment with a double-blind control procedure was no different from that in previous experiments. These data indicate that social cues were not crucial for Sadie's choice on adjacent or nonadjacent trials.

### General Discussion

Three chimpanzees were trained on pairs of stimuli taken from a series of stimuli ordered according to the relative amounts of food each stimulus contained. In Experiment 1A, the chimpanzees were given training only with adjacent pairs in the series as follows: B had more food than A, C had more food than B, D more than C, and E more than D. Specifically, the chimpanzees received trials with A-B+, B-C+, C-D+, and D-E+, where + indicates that the stimulus contained one piece of food and - indicates that it contained no food. Following extensive training on these adjacent pairs, the animals were tested on a novel nonadjacent pair, BD. Sadie chose D consistently during the test, and Luvie chose D consistently during the second of two tests. Jessie and Luvie in her initial test chose D and B equally often. Coincident with consistent choice of D on the nonadjacent test trials was highly accurate performance on adjacent pairs given during the test; coincident with chance performance on nonadjacent test trials was less accurate performance on the adjacent pairs. In Experiment 1B, in which Sadie was trained on an additional adjacent pair, E-F+ and tested on nonadjacent pairs, BE and CE, she chose E.

Experiments 2A and 2B examined the importance of a linear order of the stimuli on a scale of relative food value for choice of D on BD trials and of E on BE and CE trials. The presence of a low end point and a high end point in the series of food values, as determined by the relation between A and F, was crucial for choice of D and E during the test: When Sadie was given F-A+ trials in addition to A-B+, B-C+, C-D+, D-E+, and E-F+, thereby eliminating A and F as the low and high values in the series, she no longer chose D and E on nonadjacent test trials, BD, BE, and CE (Experiment 2A). However, when given A-F+ trials, in place of F-A+, with the above adjacent pairs, she consistently chose D and E on the test trials (Experiment 2B). These experiments indicate that choices on nonadjacent trials are sensitive to certain modifications in the linear order of the stimuli in the series, e.g.,

the presence or absence of end points in the series. The final experiment, Experiment 3, used a double-blind procedure to rule out the possibility that cues from the experimenter played a crucial role in Sadie's choice on test trials.

Because manipulation of the series order affected Sadie's choice on nonadjacent trials, the results of the present experiments suggest that she had acquired a mental representation of the order of the stimuli in the series. Such a mental representation of order information is notable because the entire series was never presented to her at one time and in order and her order information had to be inferred on the basis of experience with overlapping pairs, AB, BC, CD, DE, and EF. Such an inference of a transitive series is commonly known as transitive inference (e.g., Bryant & Trabasso, 1971). The findings of Experiments 1-3 indicate that transitive inference is a fundamental reasoning process in primates (for additional discussion of reasoning in primates, see Gillan, Premack, & Woodruff, 1981).

Although the present evidence indicates that at least one chimpanzee, Sadie, and possibly a second, Luvie, can make transitive inferences, it is not clear whether transitive inference is an ability in a wide range of primates. However, previous research suggests that another primate species, the squirrel monkey, also may be able to make transitive inferences (McGonigle & Chalmers, 1977). In addition, the present experiments demonstrate transitive inference by chimpanzees only with a series of relative amounts of food. Consequently, general statements about transitive inferences by chimpanzees with other transitive series are not warranted by the data.

The use of a series of relative amounts of food in the present experiments differs from those series in previous experiments on transitive inference, which have included series of lengths (e.g., Bryant & Trabasso, 1971), weights (McGonigle & Chalmers, 1977), and heights (e.g., Sternberg, 1980). It might be suggested that the series of relative amounts of food used here would not be a transitive series but that it would simply be a set of overlapping discrimination problems

in which the food-paired stimulus was "correct" and the other stimulus was "incorrect." Thus, the adjacent pairs presented here might be thought of as A-incorrect, B-correct; B-incorrect, C-correct; C-incorrect, D-correct; and so on. Accurate choice on adjacent pairs could be accounted for by assuming that configural cues were important: The configuration AB would direct choice of B, and BC configuration would direct choice of C, and so on. However, such an explanation cannot account for consistent choice of D and E on nonadjacent pairs because the configural cues that would direct choice of those stimuli would not be present on the novel, nonadjacent pairs. In addition, had Sadie regarded the pairs of stimuli as suggested above, her choice on nonadjacent pairs would not have been sensitive to series order, as it was in Experiments 2A and 2B.

One notable feature of the experiments reported is that they obtained evidence for transitive inferences in animals that have had no language training. Thus, it is of special interest that two prominent theories of transitive inference in humans propose that language is central to this type of reasoning (Clark, 1969; Sternberg, 1980). Both theories center around (a) a lexical marking principle that suggests that certain adjectives and the relational terms derived from them, e.g., long and longer, are more easily retrieved from memory than are their opposite terms, e.g., short and shorter, and (b) a functional relations principle that suggests that in transitive inference problems, information is stored as simple conceptual relations, such as subject-verb-direct object. It is clear that these principles are relevant to experiments in which the information was presented linguistically and to linguistically competent subjects but that they are not relevant to the present experiments. These two language-oriented theories do not explain the present data on transitive inference in chimpanzees. In addition, these data indicate that language is not a necessary condition for transitive inferences.

Given that language-oriented theories cannot account for transitive inference in the chimpanzee, how might chimpanzees make transitive inferences? Theories of transitive

inference can be organized into two classes: integration theories and nonintegration theories. Nonintegration theories attempt to account for the results of transitive inference experiments by focusing on the subject's experience with each individual stimulus or pairs of stimuli. In contrast, integration theories suggest that a subject integrates information about the separate stimuli into an ordered series.

Several nonintegration accounts of the present data, e.g., those that center around the number of recency of rewards paired with a stimulus, have been shown to be insufficient to explain the data. These accounts have particular difficulty explaining Sadie's chance performance on BD, BE, and CE trials in Experiment 2A and her choice of D and E on those trials in Experiment 2B, since the experimental manipulation in those experiments only directly involved A and F, not the test stimuli, B, C, D, and E.

An additional nonintegration theory proposes a binary sampling model to account for the results of transitive inference experiments (McGonigle & Chalmers, 1977). According to this model, a subject presented with B and D retrieves a memory representation of the C stimulus to create a three-stimulus representation, BCD. The subject then examines one of the representations of the pairs of stimuli from this triad—BC, CD, or BD. The theory suggests that each of these three representations is equally likely to be sampled on any given trial but that only one is sampled per trial. If the BC representation is sampled, the subject will not choose B and will therefore choose D, on the basis of prior B-C+ training. If the CD representation is sampled, the subject will choose D, on the basis of prior C-D+ training. If the BD representation is sampled, the subject will choose randomly between B and D, since it has had no prior experience with BD trials. Thus, choice of D on BD test trials can be determined by the formula  $.33(p\bar{B}|BC) + .33(pD|CD) + .33(pD|BD)$ . Clearly, this theory suggests that choice of D on BD trials should be related to accurate choice on B-C+ and C-D+ trials, since accurate choice on those trials is a measure of  $(p\bar{B}|BC)$  and  $(pD|CD)$ . The results of Experiment 1A

showed such a relation between accurate choice on adjacent pairs and choice of D on BD trials. However, Experiment 2A showed no such relation. In that experiment, Sadie chose accurately on B-C+ and C-D+ trials during the test but seldom chose D on BD trials. As with other nonintegration theories, the binary sampling model has difficulty accounting for those experiments, Experiments 2A and 2B, that indicate choice on nonadjacent trials is sensitive to manipulations of order of the series.

Integration theories suggest that a subject integrates separately learned information in transitive inference experiments. Two widely cited integration theories, the coordination model (e.g., Bryant & Trabasso, 1971) and the spatial integration model (e.g., De Soto, London, & Handel, 1965), differ primarily with regard to the time at which integration occurs (Trabasso, 1975). The coordination model proposes that a subject has a separate representation of each pair of adjacent stimuli presented during training. Then, during the test, when presented with a novel, nonadjacent pair, e.g., BD, the subject integrates the separate representations of the pairs into a linear order and determines its choice from that order. If given a test trial with B and D, for example, the subject would coordinate its knowledge that C has more food than B with the knowledge that D has more food than C, to choose D. In contrast, the spatial integration theory suggests that the stimuli are integrated into a representation of a linear series during training, not just during a test with nonadjacent pairs. When a new stimulus is added to a series, it is inserted into the integrated representation in its proper position in the series on the basis of its magnitude relative to the other stimuli in the series. During a subsequent transitive inference test, this previously constructed series is interrogated, and a choice is made on that basis.

Both the coordination and spatial integration theories were designed to explain data like those of Experiments 1A and 1B, as can be seen in the above explication of the theories. In addition, both can account for the absence of transitive inference in Experiment 2A. First, the coordination theory

might suggest that when Sadie was given F-A+ trials, she coordinated each of the adjacent pairs, A-B+, B-C+, C-D+, D-E+, and E-F+, which led her to choose F. As she learned that F was incorrect, she may have inferred that the coordination strategy generally was no longer applicable. Thus, by abandoning the coordination strategy, she would have had no basis on which to choose consistently on nonadjacent test pairs. Later, when given A-F+ training in Experiment 2B, she may have recognized that the coordination strategy was again useful and relied on this strategy on subsequent nonadjacent pairs in that experiment. The spatial integration theory might suggest that Sadie attempted to construct a linear representation of the series of stimuli in Experiment 2A but found it impossible since the relative values of the stimuli could not be put in a linear order. Thus, she may have abandoned the linear representation and learned each pair separately. Without an integrated representation to guide her choice on nonadjacent trials, she would not be expected to consistently choose D and E. Since construction of a linear representation was possible in Experiment 2B, Sadie may have constructed such a representation again and, therefore, was able to choose D and E consistently on nonadjacent trials.

The present data do not provide evidence concerning which of the integration theories might best account for transitive inference in the chimpanzee. Data from experiments with humans generally support the spatial integration theory for that species (e.g., Trabasso, 1975). With regard to the chimpanzee, it is clear that integration theories, in general, with their focus on the representation of series order, account for all the present data on transitive inference in the chimpanzee better than nonintegration theories.

It should be noted in conclusion that none of the proposed mechanisms for the present type of reasoning, transitive inference, bear any similarity to the proposed mechanism of another type of reasoning recently studied in the chimpanzee, analogical reasoning (Gillan et al., 1981). Comparison of these two types of reasoning suggests that the classification of such apparently diverse pro-

cesses under the general label of reasoning may be more profitable for logicians than for psychologists.

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