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CHIMPANZEE RESPONDING DURING MATCHING TO SAMPLE: CONTROL BY EXCLUSION

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Three chimpanzees performed a computerized matching-to-sample task in which samples were photographs of items and comparison stimuli were geometric symbols called lexigrams. In Experiment 1, samples were either defined (i.e., they represented items that were associated already with a specific lexigram label by the chimpanzees) or undefined (i.e., they did not have an already learned association with a specific lexigram). On each trial, the foil (incorrect) comparison could be either a defined or an undefined lexigram. All 3 chimpanzees selected the correct comparison for undefined samples at a level significantly better than chance only when the foil comparison was defined. In Experiment 2, three comparisons were presented on each trial, and in Experiment 3, four comparisons were presented on each trial. For Experiments 2 and 3, the foil comparisons consisted of either defined or undefined comparisons or a mixture of both. For these two experiments, when the chimpanzees were presented with an undefined sample, they typically made selections of only undefined comparisons. These data indicate that the chimpanzees responded through use of exclusion. A final experiment, however, indicated that, despite the use of exclusion to complete trials with undefined samples correctly, the chimpanzees did not learn new associations between undefined samples and comparisons.

Key words: exclusion, conditional discrimination, matching to sample, joystick movement, chimpanzees

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Exclusion (also called control by exclusion) is described as the selection of an undefined test stimulus over a defined test stimulus when the presented sample is undefined (Dixon, 1977; Tomonaga, 1993). The term *defined* here refers to stimuli already trained in conditional relations, and *undefined* refers to stimuli that have no preestablished relation with other nonidentical stimuli (Tomonaga). If an organism responds by exclusion when presented with an undefined sample stimulus, comparison stimuli with learned associations with other samples are eliminated as potential correct responses.

Children clearly use exclusion. Ackerman and Emmerich (1978) presented children with a recognition memory task in which multiple pairs of items were presented, and the children were told to remember that those items went together. In a subsequent recognition task, samples were either members of one of those pairs or novel items. The comparisons also consisted of novel items or the corresponding members of one of the pairs presented earlier. When the children were presented with a novel sample, they were significantly more likely to select a novel comparison than would be expected by chance. This result indicates that the children eliminated the familiar comparisons on the basis of their association with other stimuli.

Exclusion also is evident in vocabulary learning. If children know the name for an object, they usually will not accept another name for the same object. Instead, they assign that label to a novel item (Markman & Wachtel, 1988). When presented with a novel name, children will invariably match that name to a novel item (Wilkinson, Dube, & McIlvane, 1998). In addition, some studies have indicated that both normally developing children and children with mental retardation will learn new associations between these novel stimuli (Ferrari, de Rose, & McIlvane, 1993; McIlvane, Kledaras, Lowry, & Stoddard, 1992; Stromer, 1989). The use of exclusion by children may imply that the children recognize that each item in a pair is associated with only that other item of the pair. For ex-

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ample, in the case of learning words for items, each word describes only one item, and each item has only one name.

Schusterman, Gisiner, Grimm, and Hanggi (1993) suggested two ways in which comparative research on the topic of exclusion is important. First, if exclusion is used by nonhuman animals, then the principle may be dissociated from verbal behavior. Second, if the phenomenon is widespread, it may offer an appropriate means for training new conditional discriminations. We offer a third way in which comparative data are important. The demonstration of responding through use of exclusion in nonhuman animals may indicate that nonhuman animals also may have a tendency to treat each sample as being associated with a unique comparison.

Conditional discriminations by nonhuman animals often are evaluated through a matching-to-sample (MTS) procedure. The MTS procedure is employed to study numerous aspects of animal cognition (Schusterman et al., 1993), and it is particularly useful in examining learning of relations between stimuli. Although there are various types of MTS tasks, in one version of conditional MTS, each response is made to a specific comparison stimulus that is associated with but is not physically identical to a given sample. For example, an organism may be presented with a sample in one form (e.g., a photograph of an item), and then multiple stimuli comprising the set of comparison items of a different form (e.g., arbitrary geometric forms) are presented. In this task, the correct response cannot be determined by the physical similarity of a given comparison to the sample. Rather, the relation between each sample and its corresponding test stimulus is based on learning to associate a given stimulus in one form (a geometric form) with a stimulus of another form (a photograph).

In MTS tasks, normal adult human participants exhibit control by exclusion (McIlvane et al., 1987; Meehan, 1995; Stromer, 1989) as do human adults with mental retardation (Dixon, 1977). Normal children (McIlvane, Munson, & Stoddard, 1988; Stromer) and mentally retarded children also exhibit control by exclusion (McIlvane et al., 1992; McIlvane & Stoddard, 1981) on MTS tests. As noted, the use of exclusion in these participants often leads to new learned associations between the formerly novel stimuli. However, evidence of control by exclusion in nonhuman animals varies. Pigeons failed to show evidence of control by exclusion (Cumming & Berryman, 1961) although there is evidence for discriminative control by the negative stimulus (S−) (Zentall, Edwards, Moore, & Hogan, 1981).

After considerable training involving associations between gestures and objects, a dolphin (Herman, Richards, & Wolz, 1984) and a California sea lion (Schusterman & Krieger, 1984) came to associate novel gestures with novel items as long as only one available item on a given trial was novel. Schusterman et al. (1993) reported that in tests for exclusion, the sea lion Rocky was presented with a novel gesture in the presence of a novel item and a familiar item in her pool. Rocky selected the novel item when presented with a novel gesture on significantly more trials than would be expected by chance. These results were replicated with a 2nd sea lion in a similar test situation. A 3rd sea lion exhibited control by exclusion in selecting novel comparisons when novel samples were displayed in a traditional MTS conditional discrimination task. Schusterman et al. stated that the sea lions' choice of novel comparison stimuli was based on their exclusion of the trained comparison stimuli and not on their having learned new associations between novel comparison stimuli and novel samples. Unlike with human children, new conditional discriminations were not learned through use of exclusion.

Evidence of control by exclusion in chimpanzees also varies across experimental test situations. Tomonaga, Matsuzawa, Fujita, and Yamamoto (1991) did not find evidence of exclusion in a standard conditional discrimination task when novel samples and comparisons were presented. Tomonaga (1993), however, reported evidence of exclusion for a "symmetry-emergent" chimpanzee (Tomonaga et al., 1991). Symmetry refers to learning to match a sample to its corresponding comparison and then transferring this association immediately by selecting the sample when presented with the comparison. For purposes of examining exclusion, this chimpanzee was trained on color-to-shape matching and shape-to-color matching. To assess control by exclusion, undefined samples and comparisons were presented in the conditional matching tasks, and the undefined comparisons always were paired with defined comparisons (i.e., there were two choices on each trial, one defined and one undefined). The chimpanzee excluded defined comparisons and selected undefined comparisons when presented with an undefined sample at levels significantly better than chance for the color-sample trials. Exclusion, however, was not evident in the shape-sample trials.

In addition, it was found that the chimpanzee, like the sea lions (Schusterman et al., 1993), exhibited no learning by exclusion. Although she chose by exclusion, she did not learn new associations between undefined samples and undefined comparisons. Rather, the chimpanzee's selection of the undefined comparisons in response to undefined samples in the exclusion test was the result of the relations between undefined samples and excluded comparisons (Tomonaga, 1993). During these exclusion tests, selections of undefined comparisons were not differentially reinforced, and Tomonaga suggested that such reinforcement may lead to the learning of new conditional discriminations by exclusion.

Hashiya and Kojima (2001) also reported choice by exclusion in a chimpanzee. In these auditory-visual intermodal tests, the chimpanzee was presented with an unfamiliar human voice and a picture of both a familiar human face and an unfamiliar face. The chimpanzee excluded the familiar face on 75% of the trials. Therefore, in at least two experimental investigations, evidence of choice by exclusion by chimpanzees has been found. In one of these tests, a cross-modal MTS test was used. In the other test, a "special" chimpanzee that was one of the few chimpanzees tested to show evidence of symmetry served as the subject (nonhuman animals do not consistently show evidence of symmetry; Dugdale & Lowe, 2000; Sidman et al., 1982). Thus, evidence of choice by exclusion by chimpanzees is present but is not ubiquitous.

In the present experiment, 3 language-competent chimpanzees were presented with trials in which exclusion of certain comparisons was possible. These animals have established numerous associations between geometric symbols called lexigrams and items found in the environment. For the present paper, the debate on the symbolic nature of lexigrams for chimpanzees will not be a focus. Leaving the reader to interpret claims made for this symbolic instantiation of meaning by apes (Rumbaugh, 1977; Rumbaugh & Savage-Rumbaugh, 1994; Savage-Rumbaugh, 1986; Savage-Rumbaugh & Lewin, 1994; Savage-Rumbaugh et al., 1993), we focus instead on the chimpanzees' choice by exclusion in a conditional MTS task.

The associations that these chimpanzees have formed between real-world items and their lexigram counterparts are robust and long lived (Beran, Pate, Richardson, & Rumbaugh, 2000; Beran, Savage-Rumbaugh, Brakke, Kelley, & Rumbaugh, 1998; Savage-Rumbaugh, 1986). In a computerized test, these animals select the appropriate lexigram when presented with a photograph of a familiar object that has a lexigram associated with it. Therefore, tests for exclusion can be conducted using these familiar photographs and lexigrams as well as novel lexigrams and photographs of items with no learned lexigram label.

Savage-Rumbaugh (1986) reported that the 2 language-trained chimpanzees, Sherman and Austin, showed evidence of learning by exclusion in their language acquisition. Having learned many lexigram-to-item associations, the chimpanzees were exposed to seven new lexigrams. When novel food items were presented, they adopted these "unassigned" lexigrams as the label for these foods (Cerutti & Rumbaugh, 1993). Savage-Rumbaugh further noted that these associations were maintained. These data differ from the findings of Tomonaga (1993) and Schusterman et al. (1993) that indicate that learning new conditional discriminations through use of exclusion does not occur. There were differences, however, in the level of exposure to these new associations for Sherman and Austin compared to the other animals that have demonstrated use of exclusion. Sherman and Austin were allowed to use their new lexigrams to request items in addition to using these lexigrams in performing conditional discriminations, and this almost certainly aided in the learning of these new associations.

A series of studies (Beran et al., 1998; unpublished data, see below) designed to examine long-term retention of lexigram-photo associations indicated that 3 chimpanzees may have been excluding certain comparisons when a presented sample was undefined because those excluded comparisons already were defined. The present study, however, was the first to investigate the extent to which this was true. Our first purpose in conducting the present series of experiments was to provide additional data regarding chimpanzees' use of exclusion in conditional MTS. Second, we were interested in the extent to which multiple defined comparisons would be excluded instead of just the single defined comparison usually presented in experiments designed to examine the use of exclusion. Thus, we included experiments in which three and four comparisons were presented on each trial, which allowed differing numbers of defined comparisons to be presented. Finally, we sought to determine if reinforcement of the appropriate choice through use of exclusion would lead to learning new sample–comparison associations (i.e., learning to select the correct comparison when choice by exclusion was not possible). This differential reinforcement was a unique aspect of this study for examining use of exclusion by chimpanzees and whether such use of exclusion resulted in new learned associations.

EXPERIMENT 1

Method

Subjects. The 3 chimpanzees (*Pan troglodytes*) observed in this experiment were Lana (female, 30 years of age), Sherman (male, 28 years of age), and Panzee (female, 15 years of age). These chimpanzees had been involved in comparative research projects focused on language acquisition (Rumbaugh, 1977; Savage-Rumbaugh, 1986), numerical competence (Beran, 2001; Beran & Rumbaugh, 2001; Rumbaugh, Hopkins, Washburn, & Savage-Rumbaugh, 1989), memory (Beran et al., 2000; Menzel, 1999), and other topics from cognitive psychology and neuropsychology (e.g., Beran, Savage-Rumbaugh, Pate, & Rumbaugh, 1999; Hopkins, Morris, Savage-Rumbaugh, & Rumbaugh, 1992; Hopkins, Washburn, & Rumbaugh, 1990; Johnson-Pynn, Fragaszy, Hirsh, Brakke, & Greenfield, 1999).

Each chimpanzee had an established vocabulary of defined lexigrams ascertained recently through computerized MTS tests (Beran et al., 1998). *Vocabulary* here refers to learned associations between geometric symbols called lexigrams and items found in the environment. The chimpanzees were not deprived of food or water at any time during this experiment, and food items used for reinforcement were supplementary to their basic daily diet.

Apparatus. The computerized apparatus consisted of a Compaq DeskPro with an attached Kraft Systems joystick. The joystick was attached to the chimpanzees' home cage such that the chimpanzees could manipulate the joystick with their hands. The MTS program used for testing was written in Visual Basic for Windows.

Procedure. The same stimuli (consisting of photos and lexigrams) were used with all of the chimpanzees in all experiments. All of the photos were of items that were familiar to the chimpanzees. Each photo was associated with a single lexigram. There were eight defined sets of stimuli (i.e., photos for which the apes could correctly select the corresponding lexigram at high levels) and eight undefined sets of stimuli (i.e., photos for which the apes did not know the corresponding lexigrams). The defined stimuli included the photo–lexigram for banana, bread, carrot, chow (protein supplement), Coke®, juice, M&M®, and orange. The undefined stimuli included the photo–lexigram for fruit bars, broccoli, hard candy, nail clippers, animal crackers, chocolate milk mix, prunes, and shredded wheat cereal. Prior to the beginning of this experiment, each of the 16 photos was presented for four trials each as the sample in an MTS paradigm similar to the one described below, and four lexigram comparison stimuli were presented on each trial (see Figure 1). All 3 chimpanzees selected, at levels significantly better than chance, the correct comparison for defined samples but not for undefined samples (unpublished data; see Table 1).

In the present experiment, at the start of a trial, a color photo of an item was presented to a chimpanzee as the sample stimulus. The photo was in the center of the computer monitor, and the chimpanzee moved a cursor into contact with that photo through manual manipulation of the joystick. When the photo was contacted, two lexigrams were presented,

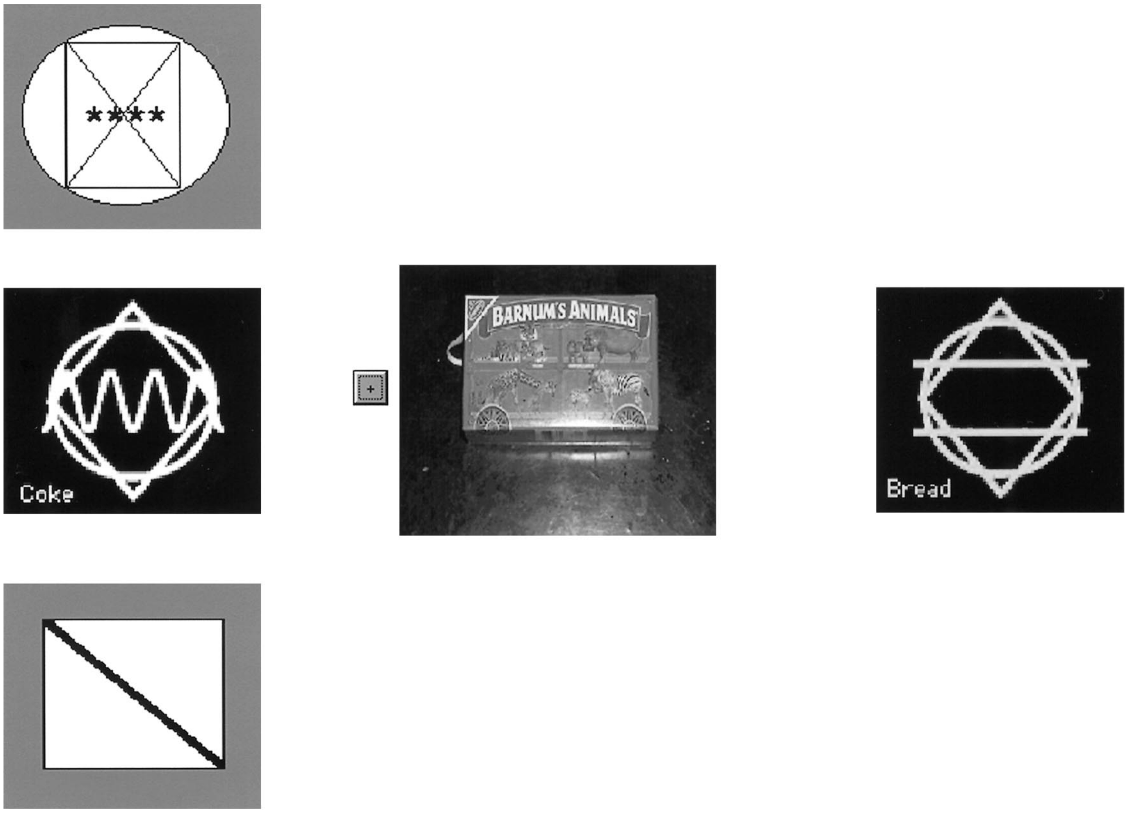

Fig. 1. An example of an experimental trial. The photo in the center of the screen is the sample (a box of animal crackers). The comparison stimuli are animal crackers (top left), Coke® (middle left), broccoli (bottom left), and bread (middle right). Thus, this trial had an undefined sample, two undefined comparisons, and two defined comparisons. The small square is the cursor. All photos and lexigrams were presented in full color.

each in one of six randomly selected positions around the perimeter of the screen. Only one of the presented test stimuli was the correct lexigram associated with the item in the photo. The foil (incorrect) lexigram was either a defined comparison (i.e., was one of the eight lexigrams consistently associated with a specific photo by the chimpanzees) or was an undefined comparison (i.e., was one of the eight lexigrams that had no previous learned association with a photo or real-world item). The chimpanzee moved the cursor into contact with one of the comparison stimuli. If the correct comparison was selected, a melodic tone sounded and the chimpanzee received food from an experimenter. If the response was incorrect, a buzz tone sounded, the chimpanzee received no food, and the next trial was presented. There was a 1-s intertrial interval before a new sample stimulus was presented. The experimenter who dispensed food for correctly completed trials was seated next to the computer but was unaware of the sample and the test stimuli that were presented so as to control for possible social cues. The food used for experimental sessions (e.g., peanuts, grapes) differed across sessions but was never a food represented in the set of test stimuli.

The sample type (defined or undefined) was randomized within 16-trial blocks such that one presentation with each sample was given within each block. Foil comparisons were selected randomly from the set of lexigram stimuli for each trial (i.e., from the 15 stimuli that were not the correct comparison for that sample). Whether the foil comparison was defined or undefined was randomly determined by the program for each trial. A defined sample was presented on 80 trials, and an undefined sample was presented on

Table 1

Performance during previous vocabulary test with defined and undefined stimuli.

Stimuli	Correct/total		
	Lana	Sherman	Panzee
Defined			
Banana	4/4	4/4	4/4
Bread	4/4	4/4	3/4
Carrot	4/4	4/4	4/4
Chow	4/4	4/4	4/4
Coke®	3/4	4/4	4/4
Juice	4/4	4/4	4/4
M&M®	4/4	4/4	4/4
Orange	4/4	4/4	4/4
Total	31/32**	32/32**	31/32**
Undefined			
Fruit bars	2/4	0/4	2/4
Broccoli	1/4	2/4	0/4
Hard candy	0/4	0/4	1/4
Nail clippers	1/4	1/4	2/4
Animal crackers	2/4	1/4	2/4
Chocolate milk mix	1/4	0/4	0/4
Prunes	2/4	0/4	2/4
Wheat cereal	1/4	0/4	2/4
Total	10/32*	4/32*	11/32*

* $p > .05$.
** $p < .01$.

80 trials. All 3 chimpanzees completed all trials in one session.

Results

The results are presented in Table 2. With defined samples, all chimpanzees selected the correct lexigram at near-perfect levels when the foil lexigram was either undefined or defined. With undefined samples, performance was significantly better than chance (50%) only for trials in which one of the two test stimuli was defined. Lana was correct on seven of eight first trials with undefined samples and one defined comparison that could be excluded. Sherman was correct on eight of eight first trials with undefined samples and one defined comparison that could be excluded. Panzee was correct on seven of eight first trials with undefined samples and one defined comparison that could be excluded.

Discussion

These 3 chimpanzees excluded defined comparisons when presented with an undefined sample. In addition, first-trial performance in which one comparison could be excluded resulted in near-perfect performance.

Table 2

Performance in Experiment 1.

Condition	% Correct		
	Lana	Sherman	Panzee
Sample (D), foil (U)	100* $N = 41$	98* $N = 48$	100* $N = 42$
Sample (D), foil (D)	97* $N = 39$	100* $N = 32$	100* $N = 38$
Sample (U), foil (U)	49 $N = 43$	51 $N = 37$	63 $N = 38$
Sample (U), foil (D)	84* $N = 37$	100* $N = 43$	91* $N = 42$

Note. D = defined, U = undefined.
* $p < .01$, binomial, chance estimated at 50%.

Performance overall, however, did not exceed chance levels when the sample was undefined and both comparisons were undefined.

In the second experiment, we presented three comparisons on each trial. We were interested in whether the chimpanzees would exclude multiple defined comparisons when presented with one of the undefined samples. We also were interested in whether any new associations between undefined samples and comparisons had been learned in Experiment 1. If such learning had occurred, performance in Experiment 2 should exceed chance levels with these undefined samples even when the effects of responding on the basis of exclusion are taken into account. In other words, if learning had occurred, performance with undefined samples should exceed chance levels based on the number of undefined comparisons present.

EXPERIMENT 2

Method

Subjects. The same 3 chimpanzees as in Experiment 1 were observed.

Apparatus. The same apparatus as in Experiment 1 was used.

Procedure. Sessions consisted of trials with three comparison stimuli. The same stimuli were used as in the previous experiment. Thus, for defined samples, the comparison stimuli consisted of either one, two, or three defined comparisons with the remaining comparisons being undefined. For undefined samples, the comparison stimuli consisted of

Table 3
Performance in Experiment 2.

Condition	% Correct Lana	Sherman	Panzee
Sample (D), foils (UU)	94* $N = 80$	100* $N = 61$	98* $N = 155$
Sample (D), foils (DU)	96* $N = 110$	98* $N = 121$	99* $N = 139$
Sample (D), foils (DD)	94* $N = 50$	100* $N = 58$	100* $N = 43$
Sample (U), foils (UU)	40 $N = 45$	55* $N = 40$	37 $N = 54$
Sample (U), foils (DU)	57* $N = 130$	50* $N = 136$	69** $N = 118$
Sample (U), foils (DD)	83* $N = 65$	86* $N = 64$	97* $N = 68$

Note. D = defined, U = undefined.
* $p < .01$, binomial, chance estimated at 33%.
** $p < .01$, binomial, chance estimated at 50% to presuppose use of inclusion.

either zero, one, or two defined comparison stimuli with all remaining comparisons being undefined. Each chimpanzee received 480 trials. A defined sample was presented on 240 trials, and an undefined sample was presented on 240 trials. All 3 chimpanzees required four sessions to complete the 480 trials (two sessions of 160 trials and two sessions of 80 trials). All other aspects of the procedure were identical to Experiment 1.

Results

The results are presented in Table 3. As expected, with defined samples, all 3 chimpanzees selected the correct lexigram at near-perfect levels independent of the type of foil lexigrams presented. In addition, when undefined samples were presented and all foil comparisons were defined, the chimpanzees performed at high levels. This again indicated that the chimpanzees were excluding defined comparisons. Sherman was also significantly better than chance (33%) on trials with undefined samples and two undefined foil comparisons. We used a modified chance level to take into account the chimpanzees' use of exclusion. To test for learning, defined comparisons were not counted in calculating the chance level (i.e., when one foil was defined, chance was estimated at 50% rather than 33%). With this modification, Panzee was significantly better than chance for undefined samples presented with one defined foil and one undefined foil.

Discussion

The chimpanzees again excluded defined comparisons when presented with an undefined sample. Performance was not as high when undefined samples were presented and only one of the foil comparisons was defined as when both foils were defined. There was some indication that 2 of the chimpanzees (Sherman and Panzee) may have learned new associations between undefined photos and lexigrams. To examine further the extent to which defined comparisons would be excluded when an undefined sample was presented, we next presented the chimpanzees with trials in which four comparisons were presented. Again, if the chimpanzees had learned new associations between undefined stimuli (photos and lexigrams), performance should exceed chance levels modified to account for use of exclusion.

EXPERIMENT 3

Method

Subjects. The same 3 chimpanzees were observed.

Apparatus. The same apparatus was used as in the previous experiments.

Procedure. Sessions consisted of trials with four comparison stimuli. The same stimuli were used as in the previous experiments. Thus, for defined samples, the comparison stimuli consisted of either 1, 2, 3, or 4 defined comparisons, with the remaining comparisons being undefined. For undefined samples, the comparison stimuli consisted of either 0, 1, 2, or 3 defined comparisons, with the remaining comparisons being undefined. Each chimpanzee received 640 trials. A defined sample was presented on 320 trials, and an undefined sample was presented on 320 trials. Sherman and Lana each completed four sessions of 160 trials. Panzee completed two sessions of 160 trials and four sessions of 80 trials. All other aspects of the procedure were identical to Experiments 1 and 2.

Results

The results are presented in Table 4. As expected, with defined samples, all 3 chimpan-

Table 4
Performance in Experiment 3.

Condition	% Correct Lana	Sherman	Panzee
Sample (D), foils (UUU)	97* $N = 38$	100* $N = 36$	97* $N = 36$
Sample (D), foils (DUU)	99* $N = 139$	99* $N = 144$	95* $N = 131$
Sample (D), foils (DDU)	97* $N = 119$	97* $N = 119$	97* $N = 132$
Sample (D), foils (DDD)	92* $N = 25$	100* $N = 21$	100* $N = 21$
Sample (U), foils (UUU)	39 $N = 23$	24 $N = 25$	41 $N = 22$
Sample (U), foils (DUU)	39* $N = 127$	33* $N = 118$	49*** $N = 106$
Sample (U), foils (DDU)	57* $N = 128$	53* $N = 134$	64** $N = 139$
Sample (U), foils (DDD)	81* $N = 42$	77* $N = 43$	94* $N = 53$

Note. D = defined, U = undefined.
* $p < .01$, chance estimated at 25%.
** $p < .01$, chance estimated at 50% to presuppose use of inclusion.
*** $p < .01$, chance estimated at 33% to presuppose use of inclusion.

zees selected the correct lexigram at near-perfect levels, independent of the type of foil lexigrams presented. In addition, when undefined samples were presented and all foil comparisons were defined, the chimpanzees performed at high levels. Thus, we again used a modified chance level to take into account the chimpanzees' use of exclusion. Defined comparisons were not counted against the chance level. With this modification, only Panzee was significantly better than chance for trials in which undefined samples were presented and either one or two of the foils were defined.

A closer examination of trials with undefined samples indicated that the chimpanzees responded through use of exclusion (Figure 2). Three different types of trials were analyzed. In these trials, the comparison set consisted of three undefined comparisons and a defined comparison (DUUU), two defined and two undefined comparisons (DDUU), or three defined comparisons and an undefined comparison (DDDU). For each of these trial types, all 3 chimpanzees selected an undefined comparison significantly more often than would be expected by chance, all $\chi^2(1) > 31.0$, $p < .01$.

Discussion

The chimpanzees again excluded defined comparisons when presented with an undefined sample. Performance was not as high when undefined samples were presented and one, two, or three of the foil comparisons were undefined as when all foils were defined. There was no indication that Sherman or Lana had learned any new associations between undefined stimuli, because their performances were at chance levels when modified to take into account the use of exclusion. Panzee's data, however, indicated that she may have learned new associations between undefined photos and lexigrams.

To clarify the extent to which the chimpanzees had learned new associations between undefined stimuli (photos and lexigrams), we conducted a final experiment in which all samples and all comparison stimuli were undefined. If any new associations between these undefined stimuli had formed, performance would exceed chance levels.

EXPERIMENT 4

Method

Subjects. The same 3 chimpanzees were observed.

Apparatus. The same apparatus was used as in the previous experiments.

Procedure. This experiment took place in a single session. All samples were undefined, and all comparisons were undefined lexigrams (i.e., the samples were the eight photos of fruit bars, broccoli, hard candy, nail clippers, animal crackers, chocolate milk mix, prunes, and shredded wheat, and the test stimuli consisted of the set of eight lexigrams corresponding to those photos). All trials during the final session involved the presentation of four comparisons consisting of the correct lexigram and three randomly selected undefined foils. Each sample was presented for 10 trials, and sample photos were randomly presented within eight-trial blocks such that each sample was presented once in each block. All other aspects of the experimental procedure were identical to the previous experiments.

Results

Neither Lana's performance (31% correct) nor Sherman's performance (29% cor-

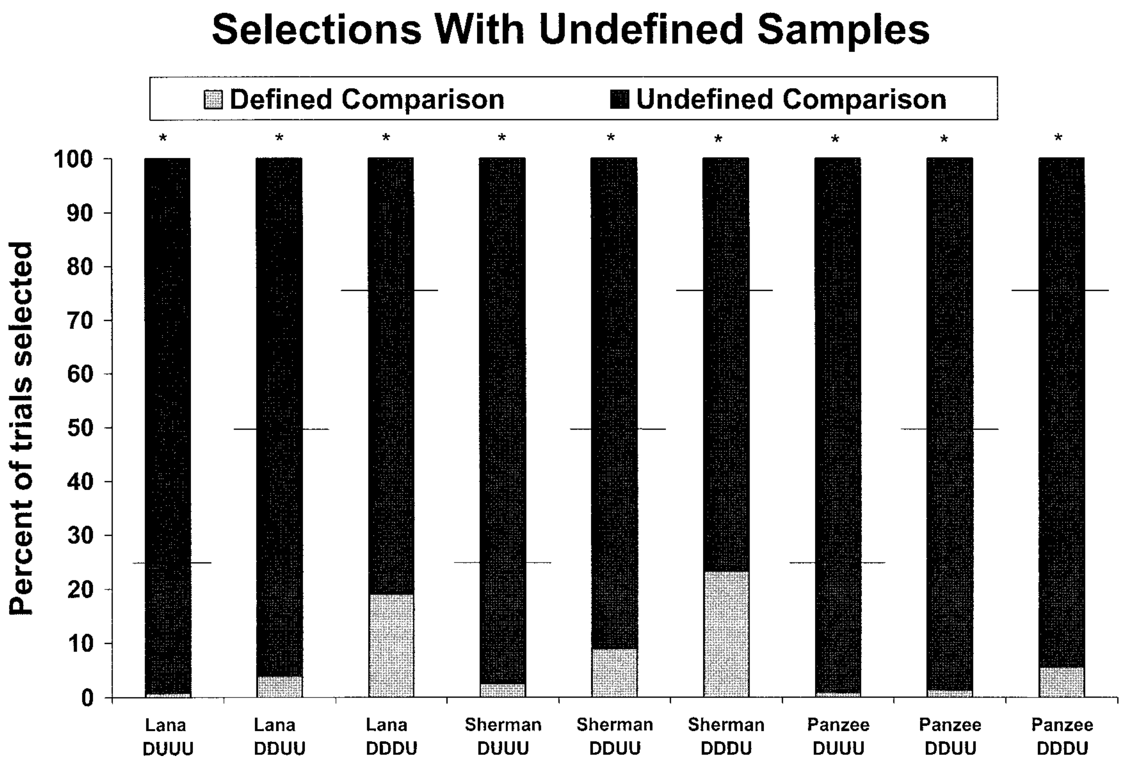

Fig. 2. Selections made by the chimpanzees for undefined samples when comparison sets contained at least one defined and one undefined comparison. The letters listed below the chimpanzees' names represent the type of comparison items presented (D = defined; U = undefined). The thin horizontal lines on the bars indicate the chance levels at which a defined comparison should have been selected. $^*p < .01$.

rect) was significantly better than chance in selecting the correct lexigram when presented with undefined samples and four undefined comparisons, Lana, $\chi^2(1, N = 80) = 1.7$, $p > .05$; Sherman, $\chi^2(1, N = 80) < 1.0$, $p > .05$. Panzee, however, performed at a level significantly better than chance, $\chi^2(1, N = 80) = 19.3$, $p < .01$. Panzee's overall performance was 46% correct, and her performance was inflated by a 100% correct performance with one item (chocolate milk mix) and 80% correct performance with another (hard candy), whereas she was not more than 50% correct with any other item. In addition, she selected those two lexigrams (hard candy and chocolate milk mix) on almost 60% of the trials in which they were available, indicating a bias toward selecting those items that may have enhanced her performance for those samples.

Discussion

There was no systematic indication that any new associations had been learned between undefined photos and lexigrams by any of these chimpanzees. This was true despite the fact that all 3 chimpanzees had received food reinforcement on a large number of trials in which undefined comparisons were selected correctly. Lana received food on 364 such trials, Panzee received food on 430 such trials, and Sherman received food on 356 such trials. Although it is almost certain that, given enough experience, the chimpanzees would learn to associate these undefined stimuli, such learning did not occur as a result of use of exclusion in these experiments.

GENERAL DISCUSSION

In all of the experiments in which exclusion could be used, the chimpanzees' responses were consistent with its use. That is, when the chimpanzees were presented with a photo of an object without a defined comparison stimulus, performance consistently depended on the opportunity to eliminate foil comparisons that were previously associated with other samples. The more comparisons that were defined, the higher the likelihood the chimpanzees would select the correct comparison for the undefined sample. In addition, the chimpanzees selected defined comparisons significantly less often than would be expected by chance when the sample was undefined. Therefore, the chimpanzees' responses on these trials were based on the use of exclusion.

In contrast to other studies of use of exclusion in nonhuman animals, the chimpanzees in these experiments were exposed to trials in which multiple comparisons were excluded based on the association of those comparisons with stimuli that were not the current samples. Increasing the number of defined comparison stimuli presented with an undefined sample did not increase the likelihood that the chimpanzees would select one of those defined stimuli. Therefore, the chimpanzees excluded multiple defined comparisons when presented with an undefined sample.

The current experiments demonstrate that exclusion is used by these language-competent chimpanzees. Although verbal behavior did not affect performance, this symbol competency may be important in the use of exclusion, especially considering that other claims for use of exclusion have occurred in a chimpanzee that demonstrated symmetry to a degree rarely found in nonhuman animals (Tomonaga, 1993) and in language-trained sea lions (Schusterman et al., 1993). Not only did this prior language training establish the defined lexigram–photo associations used in the present experiments, but it also likely predisposed the chimpanzees to anticipate that each sample would have one and only one associated stimulus. This important assumption is evidenced by the fact that the chimpanzees did not respond on tests of exclusion to stimuli that had been previously associated with reinforcement (and thereby associated with a particular sample) but rather were likely to avoid such stimuli. Like humans in prior studies, the chimpanzees responded on the task as if each defined lexigram name must be associated with only one item, and thus only lexigrams without defined items were appropriate labels for stimuli without prior lexigram associations.

Despite exhibiting control by exclusion, the 3 chimpanzees observed in this experiment did not learn new conditional discriminations through use of exclusion. This was the case despite repeated reinforcement for correct performance on trials in which exclusion was used. Therefore, exclusion may not be a useful tool for teaching conditional discriminations to nonhuman animals (as noted by Shusterman et al., 1993). It may be the case that a larger number of exposures to this type of trial would facilitate the learning of new conditional discriminations. As noted above, however, these undefined sample stimuli were not novel at the outset of the experiment; only the associations with specific to-be-learned lexigrams were novel. That is, these stimuli were familiar, but had not been learned in association with specific lexigrams prior to this study. Thus, it seems unlikely that a computerized MTS paradigm in which exclusion can be used by nonhuman subjects will facilitate the learning of new S+ conditional discriminations. It may even be the case that use of exclusion hinders the acquisition of new associations between the undefined comparison and undefined sample if the subject is attending more to the S− (the defined comparison) than to the S+ (the undefined comparison). In this regard, nonhuman animals tested to date have shown a clear difference compared to human children in what is learned through the use of exclusion (Ferrari et al., 1993; McIlvane et al., 1992; Stromer, 1989).

As noted by Tomonaga (1993), exclusion may imply the formation of a stimulus class. Equivalence relations (Sidman, 1986), which take the form of reflexivity, transitivity, and symmetry, also form a stimulus class. Aside from evidence of transitivity in nonhuman animals (Boysen, Berntson, Shreyer, & Quigley, 1993; D'Amato, Salmon, Loukas, & Tomie, 1985; Yamamoto & Asano, 1995) and, in some cases, claims of symmetry (Cerutti & Rumbaugh, 1993; Kojima, 1984; Savage-Rumbaugh, 1986; Tomonaga et al., 1991; but see also Sidman et al., 1982; Yamamoto & Asano, 1995), equivalence relations are not well established in nonhuman animals (McIntire, Cleary, & Thompson, 1987; Schusterman & Kastak, 1993; Sidman, 2000; Zentall & Urcuioli, 1993; see also Hayes, 1989). For 2 chimpanzees in the current experiment

(Sherman and Lana), symmetry was not evident when they were younger and had been exposed to standard symmetry tests (Dugdale & Lowe, 2000). Therefore, exclusion, as a form of control by negative stimulus relations, may not be correlated with Sidman equivalence relations, as suggested by Tomonaga (1993). Until further evidence of equivalence relations (symmetry, reflexivity, and transitivity) and use of exclusion in nonhuman animals is established, the relation between positive and negative stimulus control in nonhuman animals will remain unclear.

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