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PSYCHOLOGY & NEUROSCIENCE

Cebus cf. *apella* exhibits rapid acquisition of complex stimulus relations and emergent performance by exclusion

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Abstract

A "second generation" matching-to-sample procedure that minimizes past sources of artifacts involves (1) successive discrimination between sample stimuli, (2) stimulus displays ranging from four to 16 comparisons, (3) variable stimulus locations to avoid unwanted stimulus-location control, and (4) high accuracy levels (e.g., 90% correct on a 16-choice task in which chance accuracy is 6%). Examples of behavioral engineering with experienced capuchin monkeys included four-choice matching problems with video images of monkeys with substantially above-chance matching in a single session and 90% matching within six sessions. Exclusion performance was demonstrated by interspersing non-identical sample-comparison pairs within a baseline of a nine-comparison identity-matching-to-sample procedure with pictures as stimuli. The test for exclusion presented the newly "mapped" stimulus in a situation in which exclusion was not possible. Degradation of matching between physically non-identical forms occurred while baseline identity accuracy was sustained at high levels, thus confirming that *Cebus* cf. *apella* is capable of exclusion. Additionally, exclusion performance when baseline matching relations involved non-identical stimuli was shown.
Keywords: generalized identity matching; exclusion; video image stimuli; *Cebus* cf. *apella*.

Introduction

This study investigated relational learning in nonhuman primates. Studies in this field have indicated that the behavioral repertoire of nonhumans is fulfilled by directly trained behavior and by emergent behaviors, showing relational learning as an additional result of direct experience (Oden, Thompson, & Premack, 1988; Schusterman & Kastak, 1993; Kastak & Schusterman, 2002; Schusterman, Kastak, & Kastak, 2003; Frank & Wasserman, 2005).

Arbitrary conditional stimulus relations established via a procedure known as matching-to-sample may serve as a laboratory model of naturally occurring symbolic relations (Sidman, 1994), which has been used extensively in both humans (Sidman, 1971; Sidman & Cresson, 1973) and nonhumans

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(Blough, 1959; Cumming & Berryman, 1965; Zentall & Hogan, 1974). However, matching relations within that procedure are necessary but not sufficient to define symbolic functioning (Galvão, Soares Filho, Barros, & Souza, 2008). With nonhumans, matching repertoires typically comprise a small number of stimulus-stimulus relations (cf. Carter & Werner, 1978; Zentall, 1996; for an exception, see Wright, Cook, Rivera, Sands, & Delius, 1988). They are often characterized by substantial interindividual variability. When a given capability is claimed, the claim is often supported only by statistical evidence obtained in two-choice procedures (de Waal & Pokorny, 2008). Such procedures are considered by some as having substantial potential for experimental artifacts (i.e., false positives or false negatives; Sidman, 1987; Johnson & Sidman, 1993) because of a lack of coherence between the stimulus relations that the experimenter intends to establish and those that are actually acquired by the subject (Dube & McIlvane, 1996; McIlvane, Serna, Dube, & Stromer, 2000).

This report describes what is termed "second-generation" matching-to-sample procedures that have been developed with capuchin monkeys to minimize past sources of artifacts. These procedures involve (1) successive discrimination between sample

stimuli via a delayed matching-to-sample format, (2) stimulus displays ranging from four to 16 comparisons presented simultaneously, permitting one to define a large number of matching relations, (3) continuously variable stimulus locations to avoid developing stimulus relations involving unwanted stimulus-location compounds, and (4) careful preparation to produce accuracy levels that minimize problems in data interpretation (e.g., 90% correct on a 16-choice task, in which chance accuracy is 6%).

At the Experimental School for Primates, Federal University of Pará, Brazil, we have been interested in relational learning in *Cebus* cf. *apella* for more than 10 years (Barros, Galvão, & McIlvane, 2003). Our initial studies developed procedures to teach small numbers of conditional discriminations based on sample stimulus-comparison stimulus identity with two-dimensional stimuli. Stimuli were usually black abstract forms on a gray background that were presented in daily sessions on a touch-sensitive computer screen. Typical matching-to-sample procedures presented trials with three comparison stimuli as choices. Even with fairly small stimulus sets (e.g., three to six identity relations in the same session) and these limited comparison numbers, we obtained good evidence that capuchin monkeys could acquire generalized identity matching (i.e., matching based on sample-comparison identity with novel stimuli), although inter- and intrasubject variability was not eliminated (Barros, Galvão, & McIlvane, 2002; Galvão et al., 2005; Brino, Galvão, & Barros, 2009). That concern was addressed by multiple-exemplar training procedures that defined 24 matching relations in a same session via eight sets of three abstract forms each. *Cebus* cf. *apella* proved capable of maintaining high performance (> 90% accuracy) with these sets, including comparable accuracy when new forms were introduced. Via these procedures, we were able to establish a new baseline of at least 24 identity relations in as few as eight training sessions (Brino et al., in preparation), and three animals exhibited immediate matching generality.

In the present study, we sought to better define the limits of generalized identity relations in this species. In the first study conducted with a capuchin monkey as a subject (Raul), we assessed procedures that render the acquisition of stimulus-stimulus relations and matching generality even more efficiently. We conducted sessions more frequently (separated by only 3-4 h) using nine-choice matching procedures and a much broader range of stimulus types, including static-colored pictures of various items (e.g., form and color of plastic pieces, arthropods, pieces of fruit, animal and human forms). Choices by exclusion of arbitrary relations were evaluated within that identity baseline. In the second study with the same subject,

we also presented four-choice matching problems with video images (e.g., monkeys housed in the same facility but not the same cage as the subject).

Methods

Subjects

One male adult capuchin monkey (*Cebus* cf. *apella*) was included in the study. Raul (M14) had already been exposed to identity and arbitrary matching-to-sample training and tests of generalized matching-to-sample with uncolored abstract forms as stimuli (Galvão et al., 2005; Brino et al., 2009; Brino et al., in preparation).

The animal lived together with other three capuchin monkeys in an external cage (2.5 m × 2.5 m × 2.5 m) close to the laboratory. Four small auxiliary cages (0.5 m × 0.5 m × 0.5 m) were situated at the corners of the main cage and were used to separate the animals at daily meal time to reduce aggressive behaviors that were highly probable when the possibility of intercepting the others' access to food was allowed or when it was necessary for a staff member to enter the main cage. One auxiliary cage had one sliding door on the outside wall that was used to transport the subject into and out of the home cage. The captivity living conditions, manipulation protocol, balanced diet, veterinary care, and experimental procedures adopted over the course of the experiment were approved by the Ethical Committee for Animal Research, Federal University of Pará (license no. CEPAE-UFPA PS001/2005), and were in accordance with local and international rules on the treatment and manipulation of animals for research purposes.

Apparatus

Sessions were performed in experimental chambers (0.60 m × 0.60 m × 0.70 m) mounted in an acrylic structure contained within a larger cubicle (2.83 m × 2.43 m × 1.22 m). Access to the chamber was through a hinged door (0.35 m × 0.20 m) on the left wall. The chamber was equipped with a touch screen-equipped color monitor (1928L 19" ELO Touchmonitor, Tyco Electronics) that could be reached by the participant through a rectangular opening (0.30 m × 0.25 m) on the front wall (Figure 1). Next to the ceiling were three receptacles that delivered 190 mg Noyes food pellets via a hose connected to a Med Associates automatic pellet dispenser. All stimulus presentations and response recording was automatically managed by a computer with an Intel Pentium III processor running one of two custom-made software programs, EAM V. 4.0.04 (developed by Drausio Capobianco) or VAICOM GIF (developed by Dionne Monteiro), both for the purpose of research on simple and conditional discrete-trial discrimination. A videocamera attached to the rear wall of the experimental chamber was used to record all of the sessions.

Figure 1. Experimental chamber. The picture shows the sliding door, the touch screen monitor on the left, the pellet receptacles above, and two pellets dispensers externally and above. The door providing access to the outside is on the back wall. A videocamera could be installed externally to the right Plexiglas wall.

General procedure

Two types of sessions were run with the subject on the same day, separated by an interval of 3 to 4 h. The first session corresponded to Study 1, and the second session corresponded to Study 2. A delayed matching-to-sample procedure was used to train identity and arbitrary relations. In training, a sample was presented on the computer screen, and the subject had to respond to it. A response produced the disappearance of the sample and the presentation of the comparison. A touch of the correct comparison (identical to the sample or different from the sample in the case of arbitrary trials) was followed by a chocolate or grape sugar pellet (190 mg) and an intertrial interval (ITI) of 6 or 5 s. A touch of the incorrect comparison was followed only by the ITI. The stimulus position varied in nine locations in a 3 × 3 matrix on the monitor. Sessions were concluded after the subject completed all trials or after 5 min elapsed without a response.

Two studies were performed with the same subject. In Study 1, we trained identity and arbitrary matching in trials with nine choices using two-dimensional pictures as stimuli (Figure 2). Study 2 involved a matching procedure applied with video images of monkeys as samples and comparisons in 4-choice trials. For
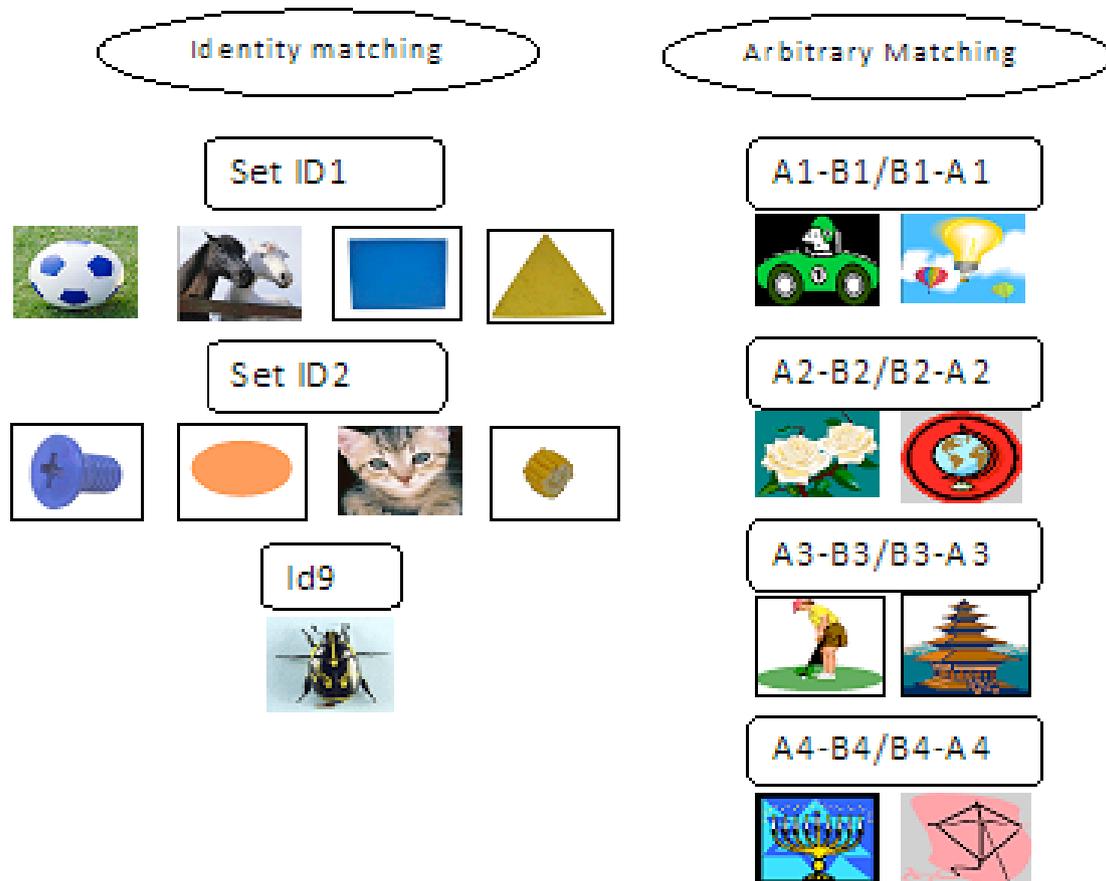
Figure 2. Pictures used as stimuli in Study 1.

technical reasons, we used 4-choice instead of 9-choice trials in Study 2. The frames of each video image used as stimuli in Study 2 are shown in Figure 3.

Study 1

The objectives of this study were to establish nine identity relations in trials that presented nine comparisons as choices to create a baseline for testing choices by exclusion in *Cebus* monkeys. Exclusion testing trials involved dissimilar sample and comparison stimuli, characterizing arbitrary relations.

In identity and arbitrary trials, a delayed matching-to-sample was designed, and three touches were required as a response to the sample. During Phase 1, a requirement of three touches of the sample was implemented to promote better control by the sample (Wright, Rivera, Katz, & Bachevalier, 2003). A change from a 0 to 1 s delay was introduced to avoid accidental touches recorded as incorrect choices.

Phase 1. Training identity matching-to-sample with pictures

Sets ID1, ID2, and stimulus Id9 (Figure 2, left) were used, which were pictures of animals, geometric figures, flowers, food, and insects. Nine identity conditional discriminations were trained in a session. A trial consisted of showing a sample (e.g., a picture of

a cat). Three touches of the sample location produced its disappearance and presentation of nine comparison stimuli after 1 s: one positive comparison (S$^+$) and eight negative comparisons (S$^-$). Sessions had 54 trials, six of each conditional discrimination. The criterion required to reach the next phase was 90% correct responses in a session. In this condition, the chance level was approximately 11% of correct responses.

Phase 2. Exclusion procedure

In these sessions, one of four arbitrary relations (A1-B1, A2-B2, A3-B3, and A4-B4; Figure 1, right) was presented in a session with eight baseline identity relations. When an arbitrary relation was introduced in training, its symmetrical relation was also presented in the same session. The subject then had to respond to eight identity discriminations and two arbitrary conditional discriminations. For example, the session could be compounded by the following relations: A1-B1, B1-A1, D1-D1, D2-D2, D3-D3, D4-D4, D5-D5, D6-D6, D7-D7, D8-D8. A trial with A1 as the sample would have the following comparisons: S$^+$ = B1, S$^-$ = D1, D2, D3, D4, D5, D6, D7, D8. Therefore, the subject could choose the S$^+$ by exclusion of eight familiar S$^-$ from the identity baseline. Sessions of exclusion with A1-B1/B1-A1 had 54 trials, and sessions with each of the other arbitrary pairs (A2-B2/B2-A2, A3-B3/B3-A3, or A4-B4/B4-A4)

Stimuli

V1

V2

V3

V4
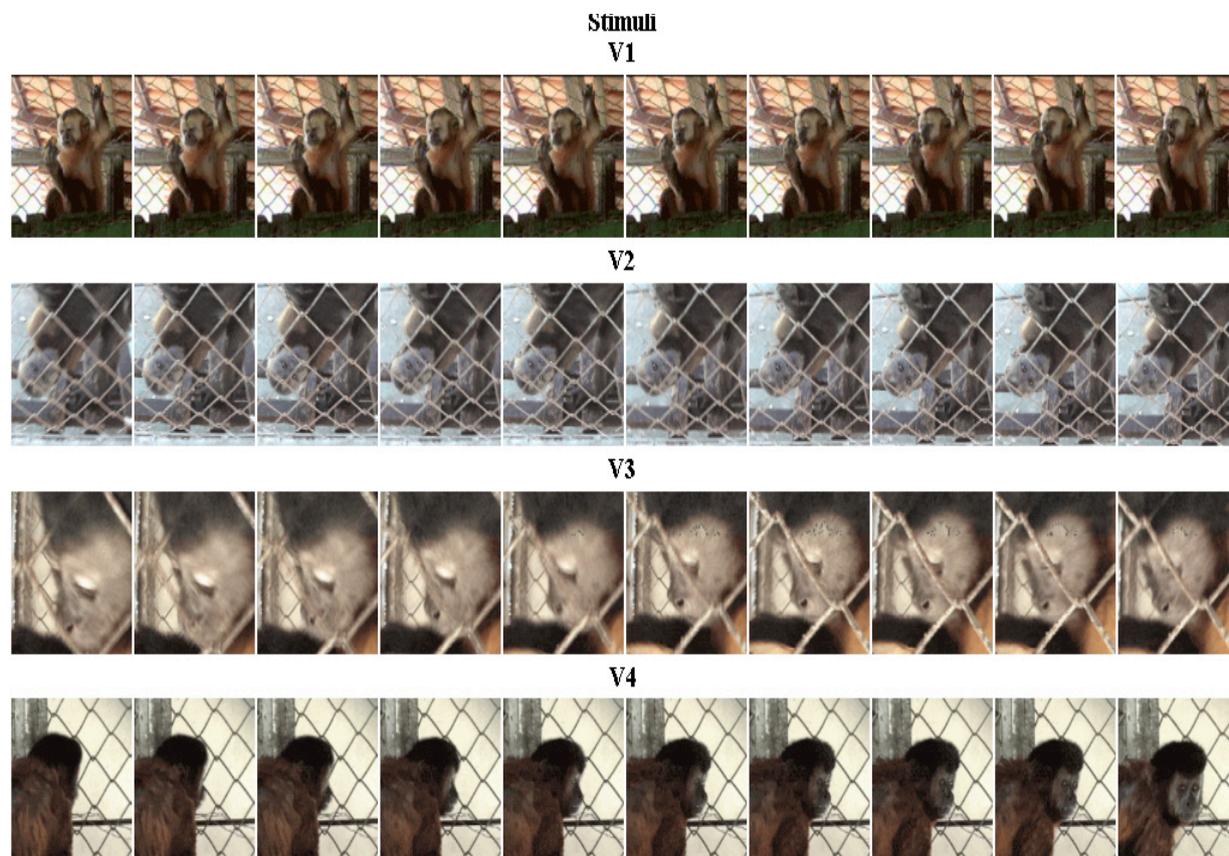
Figure 3. Frames of each video used as stimuli in Study 2. The four frames were sample and comparison stimuli of the identity training V1-V1, V2-V2, V3-V3, and V4-V4.

had 36 trials. The simultaneous training of an arbitrary relation and its symmetrical counterpart had the long-term goal of training multiple exemplars of symmetry to later assess the eventual emergence of symmetry with new arbitrary relations.
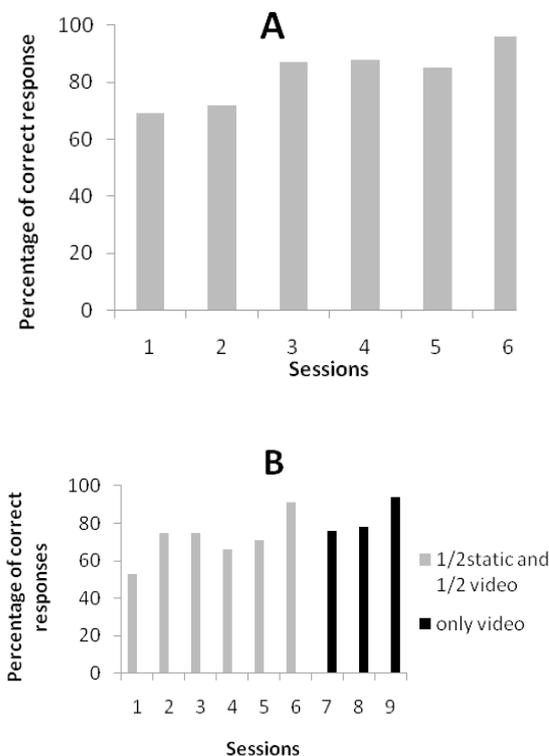
Study 2

The objective of this study was to establish matching-to-sample performance with video images of monkeys as sample and comparison stimuli. A 0-delay matching-to-sample was used in 32-trial sessions. The same number of trials of each teaching relation was presented in a session. A trial was composed of four choices as comparisons. Differential responses to each sample were required as a way to favor relational learning (McIntire, Cleary, & Thompson, 1987): Sample V1 (one touch), Sample V2 (four touches), Sample V3 (two touches), and Sample V4 (three touches).

Sixteen trials of four video image conditional identity discriminations (V1-V1, V2-V2, V3-V3, and V4-V4; Figure 3) were interspersed with 16 trials of four pictures of fruits (static stimuli). After the criterion was reached, sessions composed of only 32 video image trials were run. The criteria used to finalize both steps were (1) performance ≥ 90% correct responses of total trials, (2) ≤ two errors for each stimulus type (static or video trials), and 3) ≤ one error in each relation.

Results and Discussion

In both studies, using the second-generation matching procedures, we demonstrated ≥ 90% identity matching within six (nine choices with pictures) or nine (four choice with video images) sessions. Figure 4A shows the percentage of correct responses in the first six sessions of the 9-choice matching-to-sample with pictures (Study 1, Phase 1). Figure 4B shows the percentage in the nine sessions of 4-choice matching-to-sample with video images (Study 2). In the latter case, the first six sessions were compounded by half of the trials with static stimuli and half of the trials with videos. The last three sessions consisted of only 32 video image trials.

As a further extension of our evaluation of matching generality in *Cebus* cf. *apella*, we are now studying a procedure in which the sample is a video of a monkey performing an action, and the comparison stimulus is a continuation of this action. We have shown very high accuracy (87%) within two sessions. With regard to the identity matching in Study 1, after establishing the identity baseline with nine choices as comparisons and pictures as stimuli within this program, we demonstrated reliable exclusion performance by interspersing non-identical sample-comparison pairs within a baseline of the familiar identity performance in a 9-comparison procedure (e.g., matching novel stimulus A to physically

Figure 4. (A) Percentage of correct responses in 9-choice IDMTS procedure with pictures (Study 1, Phase 1). (B) Percentage of correct responses in 4-choice IDMTS procedure with video images (Study 2). The first six sessions consisted of half of the trials with static stimuli and half of the trials with videos. The last three sessions had only video image trials.

dissimilar novel stimulus B and *vice versa* in a baseline of matching D1 to D1, D2 to D2, D3 to D3, D4 to D4, and so on). Figure 5 shows correct and incorrect choices by exclusion in arbitrary trials (left) and the percentage of correct responses in the total trials, including identity (right), in the first session when a non-identical pair (arbitrary) was interspersed in eight identity baseline pairs. This type of session was applied to four non-identical pairs. The monkey showed almost perfect performance in the exclusion trials for four arbitrary pairs (Figure 5A) and maintained high accuracy in identity baseline (Figure 5B).

More recently, we applied critical testing sessions to evaluate learning outcomes of exclusion training, in contrast to the one-trial learning or conditional relations described above. In these sessions, we presented the newly "mapped" stimulus (A1-B1 and B1-A1 in our example) in a situation in which exclusion was not possible, thus contrasting more than the non-matching pair within the identity baseline (e.g., A1-B1 and B1-A1 contrasted with A2-B2 and B2-A2). If the A1B1 and A2B2 matching relations were not maintained, then the conclusion was that the former maps were based on excluding the familiar stimuli that appeared in the identity trials (cf. Tomonaga, 1993; Clement & Zentall,
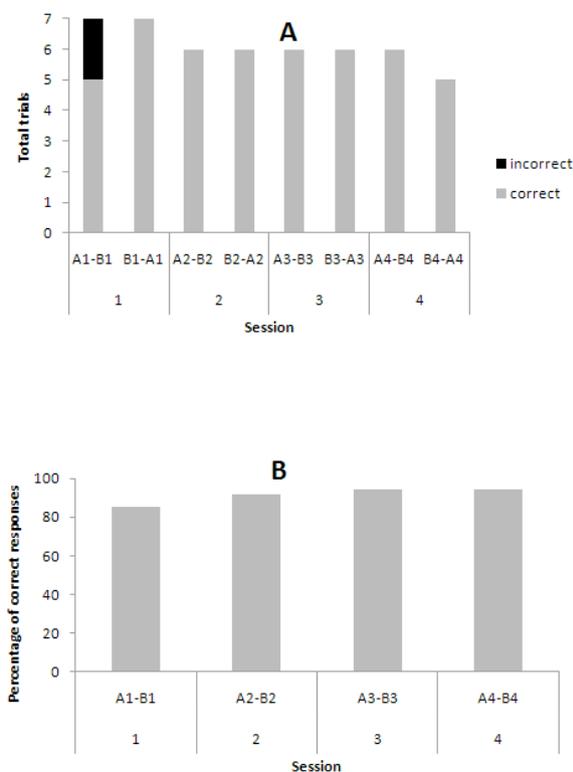
Figure 5. Data of the first session with each non-identical pair (arbitrary one) interspersed in eight identity baseline pairs. (A) Correct and incorrect choices in arbitrary trials, and (B) percent correct responses in both identity and arbitrary trials.

2003). In our study, such degradation of matching between physically non-identical forms occurred while baseline identity accuracy remained at high levels, thus confirming that *Cebus* cf. *apella* is capable of exclusion, but learning new relations is not an immediate result of the exclusion context, which is similar to performance usually observed in children with autism (Carr, 2003).

In subsequent research, we showed that *Cebus* cf. *apella* is also capable of exclusion performance when the baseline matching relations involve non-identical stimuli, performance demonstrated convincingly only recently in chimpanzees (Beran & Washburn, 2002). Yet to be established, however, are the limits of *Cebus* cf. *apella* in learning large numbers of arbitrary stimulus-stimulus relations and whether these possible limits represent a quantitative limitation of the number of such relations that can be maintained simultaneously or merely the limits of discrimination among the elements of large stimulus sets.

Acknowledgments

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