Published in final edited form as:

Behav Processes. 2011 March ; 86(3): 316–322. doi:10.1016/j.beproc.2011.01.001.

Conceptual thresholds for *same* and *different* in old-(*Macaca mulatta*) and new-world (*Cebus apella*) monkeys

Timothy M. Flemming

Department of Psychology, Language Research Center, Georgia State University, P.O. Box 5010, Atlanta, GA 30302-5010

Abstract

Learning of the relational same/different (S/D) concept has been demonstrated to be largely dependent upon stimulus sets containing more than two items for pigeons and old-world monkeys. Stimulus arrays containing several images for use in same/different discrimination procures (e.g. 16 identical images vs. 16 nonidentical images) have been shown to facilitate and even be necessary for learning of relational concepts (Flemming, Beran & Washburn, 2007; Wasserman, Young & Fagot, 2001; Young, Wasserman & Garner, 1997). In the present study, we investigate the threshold at which a new world primate, the capuchin (*Cebus apella*) may be able to make such a discrimination. Utilizing a method of *increasing* entropy, rather than conventional procedures of decreasing entropy, we demonstrate unique evidence that capuchin monkeys are readily capable of making 2-item relational S/D conditional discriminations. In another experiment, we examine the supposed level of difficulty in making S/D discriminations by rhesus monkeys (*Macaca mulatta*). Whereas pigeons (*Columba livia*) and baboons (*Papio papio*) have shown marked difficulty simultaneously discriminating *same* from *different* arrays at all when composed of fewer than 8 items each, rhesus monkeys seem to understand that pairs of stimuli connote sameness and difference just the same (Flemming et al., 2007). With sustained accurate performance of 2-item S/D discriminations, both experienced and task-naïve rhesus monkeys appear quite certain in their conceptual knowledge of *same* and *different*. We conclude that learning of the same/different relational concept may be less dependent upon high levels of entropy contrast than originally hypothesized for nonhuman primates.

Keywords

abstract concept; *Cebus apella*; concept learning; *Macaca mulatta*; monkey; same/different

The judgment of relational concepts of identity and nonidentity (*same* vs. *different*) has proven difficult and often dependent upon high levels of variability contrast for several nonhuman animal species from pigeons (*Columba livia*) to chimpanzees (*Pan troglodytes*) (e.g., Fagot, Wasserman & Young, 2001; Flemming, Beran & Washburn, 2007; Thompson & Oden, 1996; Vonk, 2003; Wasserman, Frank & Young, 2002; Wright & Katz, 2006; Young & Wasserman, 1997). Classification of items as the *same* or *different* from one

Corresponding Author: Timothy M. Flemming, Present Address: Department of Psychology, Language Research Center, Georgia State University, P.O. Box 5010, Atlanta, GA 30302-5010, voice: 404.413.5287, fax: 404.244.5829, timothy.flemming@gmail.com.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

another requires a level of abstraction (and perhaps abstract representation) beyond that which one might need for other types of concept formation.

Relational concepts, such as *same/different* and *above/below* involve a comparison of the relationship between (or among) two or more objects. These concepts thus do not depend on any absolute perceptual properties of stimuli (Zentall, Wasserman, Lazareva, Thompson & Rattermann, 2008), but rather are entirely based on the instantiation of the relation between or amongst them. Unlike most natural concepts, relational concepts are abstract in that classification based upon shared physical features of stimuli is impossible (Katz & Wright, 2006).

Judgments of identity and nonidentity are not entirely disparate from matching or non-matching to sample paradigm, but involve an additional level of assessment and computation. In a matching-to-sample (MTS) paradigm, subjects make one such equivalence computation (Thompson & Oden, 1996). In a *same/different* (S/D) discrimination task (make responses to identity but not nonidentity), one can use a similar singular equivalence computation. Finally, in a conditional S/D discrimination task wherein the subject makes responses to both identity and nonidentity based on specific discriminative cues present, two separate cognitive computations (one for identity and one for nonidentity) are required (Burdyn & Thomas, 1984). These computations, however, are no more complex individually as those utilized for matching to sample.

While the matching of specific stimulus features in common is not a viable strategy in most abstract concept learning, variability contrast has been shown to play an integral role. In one of the first demonstrations of the necessity of multiple icon arrays for the learning of the S/D concept, (and subsequent transfer to novel stimulus sets) Wasserman, Hugart and Kirkpatrick-Steger (1995) presented 16-icons arrays (*same* = 16 identical images; *different* = 16 nonidentical images) to pigeons. There was observed relatively more rapid acquisition and stronger transfer of the S/D concept with these larger displays. Young, Wasserman & Garner (1997) continued this investigation by decreasing the number of items in each stimulus array to discover incremental depreciating effects on the pigeons' performance. In addition, pigeons demonstrated marked difficulty in discriminating at all displays of fewer than 8 icons each. *Entropy*, the amount of perceptual variation within a display, is a measure of diversity in relational concepts and accounted for this variation in performance at each successively lower level in Young et al.'s (1997) task.

While humans (*Homo sapiens*) (Young & Wasserman, 2001) and great apes (e.g. *Pan troglodytes*, *Pongo pygmaeus*, *Pongo abelii*, and *Gorilla gorilla gorilla*) (King, 1973; Vonk, 2003) appear less sensitive to contrasts in entropy between stimulus displays for the extraction of conceptual information for identity and oddity, pigeons, baboons (*Papio papio*) and rhesus monkeys (*Macaca mulatta*) are all species for which entropy plays a role. For stimulus-stimulus comparison purposes, entropy is calculated by the number of pieces of information necessary to predict the categorical nature of that relational concept (Young & Wasserman, 1997). Thus, all displays of identical images, no matter the number have entropy equal to zero. Displays of all nonidentical images have entropy that increases on a logarithmic scale as the number of items contained within them increases (i.e. 2 nonidentical, entropy = 1.0; 4 nonidentical, entropy = 2.0; 6 nonidentical, entropy = 2.58). Discrimination tasks involving comparisons of higher entropy S/D displays likely reflect more perceptually-based judgments whereas a two-item S/D discrimination (entropy = 0, *same* vs. entropy = 1, *different*) lies further toward the conceptual end of a perceptual-conceptual continuum for these *same/different* judgments.

Investigations of the role of entropy in nonhuman animal relational S/D concept acquisition traditionally involve methods of reduction in the number of stimulus array items to discern the point of entropy at which subjects can no longer successfully extract relational information. Pigeons appear to be especially sensitive to changes in entropy in the acquisition of the S/D concept (e.g. Young et al., 1997). That pigeons have marked difficulty discriminating *same* from *different* with low levels of entropy contrast suggests a predisposition to attend to perceptual stimulus features over the conceptual. Rather than discriminating displays on the basis of their relational identity/nonidentity, pigeons default to a more item-specific strategy attending to (and perhaps memorizing large sets of) individual stimulus features (Wasserman, Frank & Young, 2002). In addition, pigeons show strong asymmetric preferences; pigeons found it easier to discriminate same displays from those with higher entropy than to discriminate a different (entropy 4.0) display from those with lower entropy. Further, Wasserman, Young & Ellefson's (2007) Finding Differences Model suggests a bias in pigeons for identifying nonidentity only.

Baboons (*Papio papio*) have also been shown to exhibit sensitivity to entropy contrast (among other perceptual measures such as spatial discontinuity as in Fagot & Parron, 2010) in the discrimination of *same* from *different* visual displays (Wasserman, Young & Fagot, 2001). In a pattern much like pigeons, baboons are detrimentally impacted by a reduction in the number of icons from 16 in S/D stimulus arrays. Although these animals had much greater difficulty discriminating displays of fewer than 8 icons, they could solve a matching task if the sample contained 2 icons (Fagot, Wasserman & Young, 2001). One considerable difference in the behavior of baboons was that they did not exhibit asymmetric discriminative abilities. Baboons were equally as accurate on both *same* and *different* trials, indicating that their knowledge of the S/D concept was complete, albeit its strong dependency on entropy contrast.

Capable of completing 2-item simultaneously presented S/D discriminations, rhesus monkeys (*Macaca mulatta*) utilize entropy quite differently (Flemming et al., 2007). Monkeys originally failed a 2-item (paired) S/D discrimination task for more than 10,000 trials. Within the first 500 trials of an 8-item S/D discrimination (entropy = 0, same; entropy = 3.0, different), rhesus monkeys completed the task successfully, achieving (sometimes greater than) 85% accuracy. Fleming et al. (2007) observed no decrement in performance of the rhesus monkeys with a reduction in the number of icons from 8 to 2 in the stimulus arrays; that is, immediate, spontaneous transfer was observed. In addition, like baboons, rhesus monkeys did not exhibit any preference for sameness; choice distribution of *same* and *different* was symmetric. Although monkeys were not initially able to extract conceptual-relational information from identical/nonidentical pairs, the contrast in variability of displays would seem responsible for their ultimate ability to do so. Fleming et al. (2007) concluded that while entropy was certainly vital for early relational S/D concept learning, rhesus monkeys, unlike both pigeons and baboons, were not dependent upon entropy in the further employment of the relational rule.

Recent evidence examining relational concept acquisition in new-world primate species provides support for knowledge of *same* and *different* on par with old-world species (e.g. Spinozzi, Lubrano & Truppa, 2004; Wright & Katz, 2006; Wright, Rivera, Katz & Bachevalier, 2003). In an attempt to further investigate the conceptual boundaries of their relational concept knowledge as well as the nature of entropy in *same* and *different* concepts for capuchin monkeys (*Cebus apella*), the present study utilizes a new methodology of increasing entropy whereby the minimum entropy necessary for S/D discriminations can be evaluated. In addition, conceptual thresholds, levels of difficulty with which subjects experience discriminations at successively lower levels of entropy, are investigated in the

rhesus monkey using a fluid method of entropy titration across trials for simultaneous S/D discriminations.

1.0 Experiment 1

The aim of Experiment 1 was to address further the role of entropy for capuchins (*Cebus apella*) in which knowledge of same and different are concurrently necessary in a conditional discrimination task that flexibly requires comparison of *same* vs. *different* relational information on a per-trial basis. A two-choice cued discrimination paradigm similar to the methodology of Flemming et al. (2007) previously presented to rhesus monkeys was utilized. One important difference here was that all capuchins were given the opportunity to complete a two-item (pair) discrimination before presenting displays of increased entropy. This experiment is unique in its design to *increase* entropy, rather than in a fashion of *decreasing* entropy.

1.1 Method

1.1.1 Subjects and Apparatus—Six socially-housed brown tufted capuchin monkeys (*Cebus apella*) age 2 to 18 (3 female) housed at Georgia State University's Language Research Center in Atlanta, GA, served as subjects in Experiment 1. For isolated testing, each monkey entered a small box through a door attached to the enclosure with access to a vertically-mounted joystick and visual access to a computer monitor approximately 40 cm away. All monkeys had very recently completed computer joystick training (Evans, Beran, Chan, Klein & Menzel, 2008). The only training experience that monkeys completed relevant to the present task was a standard 1 to 1 item physical matching-to-sample task.

The monkeys were not food or water deprived during the course of the study, and they had continuous access to the computerized programs for blocks of time ranging from 2 to 4 hours. Therefore, they produced varying numbers of trials (averaging 200) across sessions dependent on how long they were continued to work on the task. During this time, the computer program controlled reward (45-mg banana-flavored pellet) delivery and trial presentation. Speakers provided auditory feedback for all tasks, including a low buzzing sound for incorrect responses and an increasing crescendo sound for correct responses. These sounds had been paired with these contingencies on several previous tasks.

1.1.2 Design and Procedure—Capuchin monkeys completed either one or both of two testing phases in this experiment, each including transfer tests, based on their success in the phase 1. Beginning with the smallest stimulus relation set (2-item), monkeys completed a second phase with a larger, increased entropy-contrast stimulus array comparison (4-item *same* vs. 4-item *different*) if failure to achieve criterion in phase 1 was observed.

On each trial, two sets of clipart images (4 cm × 4 cm) were displayed: one set of physically identical objects and one pair in which each object was physically distinct. These images were commercially available set of 4,000 clipart images. All stimulus sets were composed of trial-unique clipart images. No image was ever duplicated within a testing session; after being displayed as part of any same or different set, the image was discarded and not used again until each unique stimulus was presented once. The distance between each stimulus composing the arrays was randomly determined on each trial, varying between 1–2 cm. To control for density of stimuli, these parameters were held constant across all levels (2, 4 and 6-items). Arrays were located along the top and bottom edges of the computer screen, with the location of *same* and *different* pairs being randomly determined on each trial. Stimulus sets were centered on the screen, but staggered so that the symmetry of a display was not confounded on *same* trials. Thus, no two stimuli were positioned along the same horizontal axis (controlling only for a vertical axis of symmetry – diagonal axes of symmetry were thus

still possible). For transfer tests, a completely novel set of 2,000 clipart images served as the pool from which trial-unique stimuli were drawn. In addition, arrays were controlled for density of stimuli. Arrays at every level (2, 4 or 6-items) were composed of clipart stimuli of the same size (4cm each)

Discriminative cues (background color) indicated to the monkeys which of two relations (*same* or *different*) was the correct choice on a given trial allowing for random assignment of S+ on every trial. This meant that each trial offered a new cue as to the correct response, as well as trial-unique stimuli. This flexible employment of alternating S+ in addition to the comparison between same and different choices concurrently on every given trial is a unique methodological innovation for this paradigm adapted from Flemming et al. (2007).

In both phases, if the background was colored pink, the correct response was to select the set with all identical elements. Likewise, if the background was colored black, the correct response was to select the set with all nonidentical elements. Monkeys were required to move a cursor (via their joysticks) into contact with one of the arrays by touching any area in that section of the monitor (i.e., the top or the bottom). If the contacted array was correct (S+), a banana-flavored pellet was dispensed, followed by an increasing crescendo sound. If the contacted array was incorrect, no pellet was dispensed, and a low buzzing sound was played. Inter-trial intervals of 5 seconds (correct choices) and 15 seconds (incorrect choices) were imposed. This same reward/nonreward system remained consistent throughout all phases of this experiment.

1.1.3 Phase 1—Monkeys were first presented with the two-item (pairs of stimuli) two-choice (identical versus nonidentical) cued discrimination task. This phase was considered complete when an approximate 80% criterion was achieved within a testing session (200 trials). Monkeys then completed a transfer test session of 100 trials, again with trial-unique stimuli, to verify accuracy in performance. If subjects did not achieve 80% accuracy after 1000 trials in Phase 1, testing ended and Phase 2 began.

1.1.4 Phase 2—If failure to discriminate *same* from *different* 2-item displays occurred in Phase 1, monkeys were presented with 4-item [higher entropy, *different*] displays. All procedures of this phase were the same as Phase 1, only the composition of stimulus arrays differed. Monkeys began this phase with 4-item stimulus arrays. The training portion of this phase was considered complete if an 80% criterion was achieved within a testing session (approximately 200 trials). Once criterion was achieved, subjects completed two subsequent transfer tests. The first transfer test was a 100-trial 4-item array discrimination, again with trial-unique stimuli. A final 100-trial 2-item transfer test identical to Phase 1 was completed on the next testing day.

1.2 Results and Discussion

Two capuchins spontaneously (within 200 trials) made judgments of *same* and *different* in the two-item (pair) phase of the task (entropy 0 [*same*] vs. entropy 1 [*different*]). All four remaining capuchins failed to make successful discriminative judgments with pairs of items, but succeeded in the 4-item phase within 200 trials. After successful completion and transfer to the 2-item phase, all four capuchins met an approximate 80% criterion within the first 100-trial block. See Table 1 for accuracy levels for each animal.

That 2 capuchins succeeded in making 2-item conceptual-relational discriminations of same and different spontaneously (without higher entropy contrast training as in Flemming et al. (2007) with macaques) suggests a less integral dependence on perceptual driving mechanisms in concept learning for these capuchins. Although we cannot conclude that entropy plays no role at all for these new world monkeys, 4 additional monkeys required

only a maximum of 4-item displays, compared to 8–12 items for old-world monkeys (rhesus - Flemming et al., 2007; guinea baboons - Fagot et al., 2001). Thus it would seem that the level of entropy contrast plays a reduced role for new world monkeys when compared to previous finding from old world monkeys. While it was previously concluded that relational-conceptual knowledge of *same* and *different* was largely informed by a perceptual comparison of entropy contrast, but not entropy-dependent, we find that this may be true to an even lesser extent for some new world monkeys.

2.0 Experiment 2

It is typically assumed that judgments of *same* and *different* are more difficult the fewer items a relational array contains. The aim of Experiment 2 was to determine the level of difficulty associated with varying levels of entropy for rhesus macaques in a conceptual-relational two-choice discrimination task. Magnitude of reward decreased for each successive level of increasing entropy (larger displays) Success and failure rate at each level within a trial block was determinate of shifting to levels of increased or decreased entropy contrast.

2.1 Method

2.1.1 Subjects and Apparatus—Six male rhesus macaques (*Macaca mulatta*) housed at Georgia State University's Language Research Center, age 5 to 26 completed Experiment 2. Two macaques (Hank and Gale, both age 26) had prior experience on a very similar battery of S/D tasks from Flemming et al., 2007. In these assessments, Hank and Gale successfully learned the 2-item S/D discrimination task in a paradigm of decreasing entropy beginning with 8-item sets. Although the tests were completed 4 years before the current experiment, it is worthy of mention with the current comparison to other macaques completely naïve to S/D procedures also included in the present experiment. Four macaques (Obi, age 5; Han, age 6; Luke, age 11; Chewie, age 11) naïve to S/D testing completed the same procedures in this experiment. The only training experience that these naïve macaques completed relevant to the present task was a standard 1 to 1 item physical matching-to-sample task.

Subjects were not food or water deprived during the course of the study. All rhesus macaques had continuous access to the computerized programs for blocks of time ranging from 4 hours to 24 hours. During this time, the computer program controlled reward delivery (94-mg banana flavored pellet) and trial presentation. The Language Research Center's Computerized Test System (LRC-CTS) consists of an IBM-compatible desktop personal computer (Washburn, Rumbaugh & Richardson, 1992). Each animal had access to its own testing station. During tasks, macaques controlled a cursor on a 17-inch SVGA monitor located approximately 20 cm away via a vertically mounted joystick. Speakers provided auditory feedback for all tasks, including a low buzzing sound for incorrect responses and an increasing crescendo sound for correct responses. These sounds have been paired with these outcomes on many previous tasks.

2.1.2 Design and Procedure—Testing sessions for all rhesus macaques began with cued 2-item S/D discriminations visually identical to presentation in Experiment 1 with capuchin monkeys. Macaques were able to move throughout the levels in 50 trial increments, shifting up or down or remaining at the most difficult level based on their degree of success within a 50-trial block at the current level. Under the assumption that macaques prefer a higher reward, it was expected that they always maintain or move up to the most difficult (highest payoff) level if they are capable of doing so. See Figure 1 for a depiction of sample trial types.

For 2-item (pairs) discriminations considered most difficult, rhesus macaques received 4 pellets as reward. Thus, the incentive to complete these trials was relatively (4:1) high. To remain at the current level, macaques had to meet a criterion of 40 out of the last 50 consecutive trials correct. If they performed at levels of chance (20 out of the last 50 consecutive trials incorrect) the computer would initiate a sequence of “easier” 4-item array discrimination trials. In this level of increased entropy, reward magnitude was decreased, such that reward contrast from the previous level was 2:1. If macaques met a criterion of 40 out of the last 50 consecutive trials correct (80%), the computer would immediately initiate a sequence of 2-item discrimination trials with a higher reward payoff. Alternatively, if the macaques again performed near levels of chance (20 out of the last 50 consecutive trials incorrect) the computer would initiate a sequence of the “easiest” 6-item array discrimination trials. In this level of increased entropy, reward magnitude was again decreased, such that reward contrast from the previous level was 2:1 (1 vs. 2 pellets). The same contingencies for moving up a level (decreased entropy, higher pellet magnitude) remained in place.

The same commercially available set of 4,000 clipart images from Experiment 1 was utilized in Experiment 2. As for capuchin monkeys, all stimulus sets for rhesus monkeys were composed of trial-unique clipart images. No image was ever duplicated within a testing session (500 trials). Arrays were located along the top and bottom edges of the computer screen, with the location of *same* and *different* pairs being randomly determined on each trial. Stimuli were separated by a randomly determined distance of 1–2 cm from each other. Stimulus sets were centered on the horizontal axis of the screen, but staggered so that the symmetry of a display was not confounded on *same* trials. For transfer tests, a completely novel set of 2,000 clipart images served as the pool from which trial-unique stimuli were drawn.

All macaques completed one 500-trial block within which they moved back and forth throughout the varied entropy levels. Because this task is highly susceptible to learning and asymptotic leveling with prolonged training, the macaques’ spontaneous performance was of primary interest. To assess possible sustained performance and verify accuracy of results, one 100-trial transfer test was completed 2–3 days after the initial 500-trial testing block.

2.2 Results and Discussion

All but one monkey (Luke – naïve) completed trials at the Level 3 (2-item) difficulty for more than half of the 500-trial session. All monkeys initially failed the two-item discrimination and dropped to the 4-item set, but only 2 monkeys (1 experienced, 1 naïve) failed the 4-item set trials to drop into the 6-item set discrimination. A main effect for entropy contrast (task level) was observed using a one-way ANOVA to compare the number of trials completed at each level $F(2,15) = 32.90, p < .01$ across all monkeys (both naïve and experienced). Tukey’s post-hoc analyses revealed that while the number of trials completed in Level 3, 2-item and Level 2, 4-item were distributed more evenly ($p = .057$), a significantly greater proportion of trials in the 500-trial session were completed in Level 3, 2-item than Level 1, 6-item ($p = .002$) and in Level 2, 4-item than Level 1, 6-item ($p = .006$).

Most notably, no significant effect of experience was observed at any entropy level ($p = .737$; $p = .389$; $p = .759$, respectively). In addition, no position or relation biases (choice asymmetry) were observed. See Table 2 for a summary of level transitions, number of trials performed at each level and symmetric performance verifications [i.e., percent correct was the result of an equal distribution of *same* and *different* trials correct; performance on *same* trials was equal to performance on *different* trials]. See Figure 2 for performance distribution.

In a subsequent 100-trial transfer session under the same methodological conditions, all monkeys remained at the most difficult level and never dropped into a level of higher entropy distinction. Percent accuracies ranged from 75%–93%, all significantly above chance. Accuracies for each monkey are displayed in Table 2.

That macaques were able to retain successful performance for both 2- and 4-item S/D discriminations with only minimal exposure to levels of higher entropy contrast suggests that nonhuman primates are less dependent on entropy than originally hypothesized (Flemming et al., 2007; Fagot et al., 2001). More importantly, 4 macaques naïve to any S/D task completed trials with levels of success equal to (or better than in some instances) macaques with prior experience on the task. Whereas macaques in our previous study (Flemming et al., 2007) completed the task beginning with sets of 8-items, monkeys here garnered success with very minimal exposure (150–250 trials) to displays containing as few as 4 items, rendering 6- and 8- item training redundant and unnecessary. Thus, rhesus macaques are capable of learning the relational-conceptual S/D discrimination task with entropy distinctions of only 2 (4-item *different*, entropy = 2; 4-item *same*, entropy = 0). Spending relatively fewer trials in contingencies of lower reinforcement and higher entropy (“easier”), the initial learning stages of *same* and *different* appear dependent on a lower level of entropy contrast than originally observed (Flemming et al., 2007). In addition, displays of lower entropy seem no more difficult for macaques to discriminate with success. Rather, the macaques appear quite comfortable in their knowledge of *same* and *different* without elevated levels of entropy.

3.0 General Discussion

Learning about *same* and *different* relational concepts may depend on a lower level of entropy contrast of displays than originally hypothesized (Flemming et al., 2007; Wasserman & Young, 2010). The general pattern of relational concept acquisition observed was, if not immediate for 2-item S/D discriminations, one of immediate transfer after performing trials correctly at a level of increased entropy distinction, even for animals completely naïve to S/D tasks. This study provides unique evidence that both rhesus and capuchin monkeys are capable of making *simultaneous* same/different relational discriminations with arrays of as few as 2 or 4 items [entropy contrast of 0:1 or 2]. The novel technique of gradually increasing entropy contrast rather than decreasing stimulus array number introduced in this study perhaps more accurately estimates the threshold at which nonhuman primates appear to extract conceptual information about the relations of *same* and *different*.

Because of findings in the pigeon (e.g. Young & Wasserman, 1997), baboon (Fagot et al., 2001) and rhesus monkey (e.g. Flemming et al., 2007) literatures, it is often assumed that discriminations of lower entropy distinction are more difficult for the animal. With an assumed predisposition to attend to physical properties of stimuli (Flemming, Thompson, Beran & Washburn, *in review*; Thompson & Oden, 2000), it would stand to reason that judgments of conceptual relatedness would fall under increased cognitive control for many nonhuman animals. Perhaps it is the case that gaining this level of cognitive control is not as difficult a task for the monkeys in the present study.

Wright and Katz (2006) also report an understanding of abstract sameness and difference for rhesus monkeys, capuchin monkeys, and pigeons without the use of stimulus arrays containing an entropy contrast greater than 1. Both primate and avian species used matching and nonmatching rules to judge relational sameness or difference and generalized these rules to novel stimulus sets with varying rates of acquisition, dependent on measures such as training set size, test stimuli and contingencies. While this study sheds light on the

employment of abstract match/nonmatch rules independent of one another, the current study addresses conceptually relational knowledge of same versus different by requiring the *simultaneous* discrimination of identical *from* nonidentical pairs of stimuli within a trial.

Also in contrast to other S/D discrimination studies with pigeons (e.g. Wasserman et al., 2001), Blaisdell and Cook (2005) provide evidence for simultaneous 2-item S/D discrimination in pigeons. This recent discrepancy from aforementioned studies, but corroboration with present findings from capuchin and rhesus monkeys, might be attributed to the use of rather simple geometric stimuli that encouraged a focus on the relational information present, rather than a focus on specific stimulus features as might occur with more intricate clipart icons used in previous investigations. Blaisdell and Cook (2005) utilized only 6 different geometric shapes of 6 different highly-discriminable colors. By creating 12,960 unique dimensional displays, pigeons were never given the opportunity to memorize specific stimulus combinations. By simplifying the task and removing initially perceptually-based discrimination strategies, it is perhaps the case that relational information was simply more salient and thus conceptual strategies begin to emerge. Like the utilization of trial-unique stimuli in the present study, methodology encouraging a shift in attention away from perceptual features of stimuli allows for the emergence of more conceptually-guided behavior.

Are 2-item S/D discriminations markedly more “difficult” for a nonhuman primate as previously implicated? Given the ability of *Macaca* to sustain completion of these trial types when motivated to do so with increased reward contingency, it would seem not. Taken together with the results of Flemming et al. (2007) wherein no decrement in performance was observed with decreases in entropy contrast for S/D discriminations, it is likely that rhesus monkeys are equally capable of extracting relational-conceptual information from a 2-item pair as they are from a larger stimulus array given minimal requisite exposure to larger sets. This pattern of performance seems to support the case that the conceptual-perceptual divide is often misrepresented. Goldstone and Barsalou (1998) argue that many of the same underlying cognitive mechanisms may drive both perception and conception or in the very least work in parallel. The conceptual processes used by monkeys in the current study may be the emergent result of their perceptual processes simply becoming less bound to the perceptual features of the stimuli.

In conclusion, it is certainly the case that entropy plays a slight facilitatory role for some *Cebus* individuals and *Macaca* in the acquisition of the relational concepts of both *same* and *different*. However, contrary to previous findings, both the amount of perceptual contrast and duration of training need not be as substantial as suggested for these and other nonhuman animal species. With some new-world individuals (*Cebus apella*) discriminating pairs of S/D stimuli relatively spontaneously, it is likely that the employment of relational-conceptual knowledge is at the forefront of their cognitive reasoning skills. Are new-world monkeys less perceptually-predisposed than previously hypothesized with old-world monkeys? If so, future studies with capuchins and other new-world primates may help to elucidate the supposed disconnect in perceptual-conceptual reasoning.

Acknowledgments

This research project was supported by grant HD-38051 from the National Institute of Child Health and Human Development, awarded to David A. Washburn and Georgia State University. Appreciation is given to Ted Evans for his assistance with data collection. In addition, I would like to recognize Michael J. Beran for his advisement and support in this study and several others throughout my doctoral research.

References

- Blaisdell AP, Cook RG. Two-item *same-different* concept leaning in pigeons. *Learning & Behavior*. 2005; 33:67–77. [PubMed: 15971494]
- Burdyn LE, Thomas RK. Conditional discrimination with conceptual simultaneous and successive cue in the squirrel monkey (*Saimiri sciureus*). *Journal of Comparative Psychology*. 1984; 98:405–413. [PubMed: 6210175]
- Evan TA, Beran MJ, Chan B, Klein ED, Menzel CR. An efficient computerized testing method for the capuchin monkey (*Cebus apella*): Adaptation of the LRC-CTS to a socially-housed nonhuman primate species. *Behavior Research Methods*. 2008; 40:590–596. [PubMed: 18522071]
- Fagot J, Parron C. Relational matching in baboons (*Papio papio*) with reduced grouping requirements. *Journal of Experimental Psychology: Animal Behavior Processes*. 2010; 36:184–193. [PubMed: 20384399]
- Fagot J, Wasserman EA, Young ME. Discriminating the relation between relations: The role of entropy in abstract conceptualization by baboons (*Papio papio*) and humans (*Homo sapiens*). *Journal of Experimental Psychology: Animal Behavior Processes*. 2001; 27:316–328. [PubMed: 11676083]
- Flemming TM, Beran MJ, Washburn DA. Disconnect in concept learning by rhesus monkeys: Judgment of relations and relations-between-relations. *Journal of Experimental Psychology: Animal Behavior Processes*. 2007; 33:55–63. [PubMed: 17227195]
- Flemming TM, Thompson RKR, Beran MJ, Washburn DA. Analogical reasoning and the differential outcome effect: Transitory bridging of the conceptual gap for rhesus monkeys (*Macaca mulatta*). *Journal of Experimental Psychology: Animal Behavior Processes*. in review.
- Goldstone RL, Barsalou LW. Reuniting perception and conception. *Cognition*. 1998; 65:231–262. [PubMed: 9557384]
- King JE. Learning and generalization of a two-dimensional sameness-difference concept by chimpanzees and orangutans. *Journal of Comparative and Physiological Psychology*. 1973; 84:140–148. [PubMed: 4717546]
- Spinozzi G, Lubrano G, Truppa V. Categorization of above and below spatial relations by tufted capuchin monkeys (*Cebus apella*). *Journal of Comparative Psychology*. 2004; 118:403–412. [PubMed: 15584777]
- Thompson RKR, Oden DL. A profound disparity revisited: Perception and judgment of abstract identity relations by chimpanzees, human infants, and monkeys. *Behavioural Processes*. 1996; 35:149–161.
- Thompson RKR, Oden DL. Categorical perception and conceptual judgments by nonhuman primates: The paleological monkey and the analogical ape. *Cognitive Science*. 2000; 24:363–396.
- Vonk J. Gorilla (*Gorilla gorilla gorilla*) and orangutan (*Pongo abelii*) understanding of first- and second-order relations. *Animal Cognition*. 2003; 6:77–86. [PubMed: 12687418]
- Wasserman EA, Hugart JA, Kirkpatrick-Steger K. Pigeons show same-different conceptualization after training with complex visual stimuli. *Journal of Experimental Psychology: Animal Behavior Processes*. 1995; 21:248–252. [PubMed: 7602259]
- Wasserman EA, Frank AJ, Young ME. Stimulus control by same-versus-different relations among multiple visual stimuli. *Journal of Experimental Psychology: Animal Behavior Processes*. 2002; 28:347–357. [PubMed: 12395492]
- Wasserman EA, Young ME. Same-different discrimination: The keel and backbone of thought and reasoning. *Journal of Experimental Psychology: Animal Behavior Processes*. 2010; 36:3–22. [PubMed: 20141313]
- Wasserman EA, Young ME, Fagot J. Effects of number of items on the baboon's discrimination of same from different visual displays. *Animal Cognition*. 2001; 4:163–170.
- Washburn DA, Rumbaugh DM, Richardson WK. The Language Research Center's computerized test system for environmental enrichment and psychological assessment. *Contemporary Topics*. 1992; 31:11–15. [PubMed: 11538192]
- Wright AA, Katz JS. Mechanisms of same/different concept learning in primates and avians. *Behavioural Processes*. 2006; 72:234–254. [PubMed: 16621333]

- Wright AA, Rivera JJ, Katz JS, Bachevalier J. Abstract-concept learning and list-memory processing by capuchin and rhesus monkeys. *Journal of Experimental Psychology: Animal Behavior Processes*. 2003; 29:184–198. [PubMed: 12884678]
- Young ME, Wasserman EA. Entropy detection by pigeons: Response to mixed visual displays after same-different discrimination training. *Journal of Experimental Psychology: Animal Behavior Processes*. 1997; 23:157–170. [PubMed: 9095540]
- Young ME, Wasserman EA. Entropy and variability discrimination. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2001; 27:278–2293.
- Young ME, Wasserman EA. Detecting variety: What's so special about uniformity? *Journal of Experimental Psychology: General*. 2002; 131:131–143. [PubMed: 11900100]
- Young ME, Wasserman EA, Garner KL. Effects of number of items on the pigeon's discrimination of same from different visual displays. *Journal of Experimental Psychology: Animal Behavior Processes*. 1997; 23:291–501.
- Young ME, Wasserman EA, Ellefson MR. A theory of variability discrimination: Finding differences. *Psychonomic Bulletin and Review*. 2007; 14:805–822. [PubMed: 18087944]
- Zentall TR, Wasserman EA, Lazareva OF, Thompson RKR, Rattermann MJ. Concept learning in animals. *Comparative Cognition & Behavior Review*. 2008; 3:13–45.

Figure 1.

Depiction of titrating S/D discrimination task presented to *Macaca*. All macaques began the experiment with 2-item discrimination trials. Based on accuracy, trials from the next level of increased entropy were presented. Subjects could be moved to the next level of increased entropy for performance consistent with chance or back to a level of decreased entropy for performance significantly better than chance. For simplicity, all correct responses are located along the top edge in these sample trials (this location would be randomly counterbalanced on each trial during task presentation). Absolute reward magnitude (number of pellets) is presented with each corresponding level of entropy. Arrows indicate direction of movement between task levels based on performance.

Figure 2. Proportion of 500-trial session performed in each entropy level by *Macaca* on a titrating S/D relational discrimination task. Dashed line represents chance distribution. Error bars represent ± 1 standard error.

Table 1

Performance summaries for *Cebus* on S/D relational discrimination task

Phase 1 2 items				Z
# Trials	# correct (% acc)			
Logan	200	163 (81.5%)	8.84*	
Liam	200	155 (77.5%)	7.71*	
Nala	500	266 (53.2%)	1.39	
Wren	500	271 (54.2%)	1.83	
Lily	500	244 (48.8%)	-0.49	
Gabe	500	259 (51.8%)	0.76	
Phase 2 4 items				Z
# Trials	# correct (% acc)			
Nala	200	166 (83.0%)	9.26*	
Wren	200	171 (85.5%)	9.97*	
Lily	200	160 (80.0%)	8.41*	
Gabe	200	157(78.5%)	7.99*	
Transfer 100 trials				Z
4 items (% acc)	2 items (% acc)			
Logan	-	-	85.0	6.9*
Liam	-	-	81.0	6.1*
Nala	78.0	5.5*	86.0	7.1*
Wren	84.0	6.7*	78.0	5.5*
Lily	84.0	6.7*	83.0	6.5*
Gabe	81.0	6.1*	77.0	5.3*
Mean/Group Score	81.8	12.7*	81.7	15.5*
			-0.2	1.4

* p<.01

Note: 4-item training sessions not completed for Logan and Liam due to success with 2-item training session. Only 200-trial training sessions and 100-trial transfer tests were completed by Logan and Liam. Positive z-scores for symmetry (all insignificant) indicate a preference for *top* (location) and *same* (relation) as computed by choice selection in the 100-trial session.

Table 2

Performance summaries for *Macaca* on titrating S/D relational discrimination task

Phase 1 500 trials	↑Entropy 2 to 4 shift	↓Entropy 4 to 2 shift	↑Entropy 4 to 6 shift	↓Entropy 6 to 4 shift	Remain in 2	Remain in 4	Remain in 6
Han	2	2	0	0	260	240	0
Obi	3	4	0	0	316	184	0
Luke	4	3	1	1	138	270	92
Chewie	1	1	0	0	328	172	0
§ Hank	3	2	1	1	275	152	73
§ Gale	2	2	0	0	293	207	0
Mean					268.3	204.2	27.5

Phase 2 100-trial Transfer	Remain in 2	% Correct	Z	Top/Bottom Symmetry	S/D Symmetry
Han	100	82.0	6.3*	0.7	1.3
Obi	100	78.0	5.5*	-0.3	-0.5
Luke	100	75.0	4.9*	1.1	0.5
Chewie	100	93.0	8.5*	0.9	0.1
§ Hank	100	79.0	5.7*	0.7	-1.1
§ Gale	100	86.0	7.1*	1.3	0.5
Mean/Group Score	100	82.2	15.7	1.4	-0.1

*
p < .05;

§ indicates a monkey with substantial experience on S/D relational discrimination tasks (Flemming et al., 2007)

Note. Positive z-scores for symmetry (all insignificant) indicate a preference for *top* (location) and *same* (relation) as computed by choice selection in the 100-trial session.