Japanese Psychological Research
1997, Volume 39, No. 3, 226–235
Special Issue: Cognition and behavior of chimpanzees

Choice between two discrimination tasks in chimpanzees (*Pan troglodytes*)

SHUJI SUZUKI and TETSURO MATSUZAWA
Section of Language and Intelligence, Department of Behavioral and Brain Sciences, Primate Research Institute, Kyoto University, Inuyama 484, Japan

Abstract: The purpose of the present study was to investigate the effects of cognitive effort on a chimpanzee's choice between discrimination tasks. The tasks were of the matching-to-sample type. In Experiment 1, the chimpanzee was required to choose between a task providing a high reinforcement rate with high cognitive effort and a task providing a low reinforcement rate with low cognitive effort. Her choice depended on the reinforcement rate more than the cognitive effort. Experiments 2, 3, and 4 examined whether the kind of cognitive effort influenced the chimpanzee's choice. Experiment 2 manipulated the sample-choice relationship, so-called symmetry in the matching-to-sample tasks. Experiment 3 manipulated the number of comparison stimuli. Experiment 4 manipulated the delay interval between the sample and the comparison stimuli. In Experiments 2 and 3, the effects of the cognitive effort were confounded with those of the reinforcement rates. However, in one condition of Experiment 4, the chimpanzee preferred the simultaneous task to the delayed task, despite the lack of a significant difference in reinforcement rates between the two tasks. The present study demonstrated that the chimpanzee's choice of discrimination task depended on the cognitive effort involved, in addition to the reinforcement rate.

Key words: cognitive effort, discrimination task, choice behavior, chimpanzees.

Studies in choice behavior have been performed with many species, including humans, monkeys, rats, and pigeons. Most used alternative schedules of reinforcement for responses on keys or levers, which was the physical cost. However, some alternatives necessitated not only a physical cost but also an intellectual cost in obtaining the reinforcer. One of these was the discrimination task.

In order to solve the discrimination tasks and obtain the reinforcers, it is necessary to expend cognitive effort, which was the intellectual cost. Cognitive effort is defined as the total amount of cognitive resources – including perception, memory, and judgment – needed to complete a task (Russo & Dosher, 1983). Fantino (1968) reported that the choice behavior depended on the response requirement despite the same rate of reinforcement. Then, does the choice behavior depend on the cognitive effort?

No study of choice behavior in nonhuman animals has examined cognitive effort. Therefore, the kind of cognitive effort that might influence the choice behavior of nonhuman animals is not known. The present study examined the effects of cognitive effort on choice behavior in chimpanzees. We used a discrimination task as a choice alternative, as opposed to a schedule of reinforcement. Cognitive effort was varied by manipulating the discrimination tasks.

The present study used chimpanzees as subjects for two reasons. First, few studies of choice behavior have tested the chimpanzee.

For the purpose of cross-species comparisons, the lack of studies on chimpanzees – phylogenetically the closest relatives of humans – poses a serious problem. Second, apart from humans, no species other than chimpanzee is adequate for the manipulation of cognitive effort.

The present studies consisted of four experiments. The purpose of Experiment 1 was to examine whether the reinforcement rate or the cognitive effort had a larger influence on the chimpanzee's choice behavior. In Experiment 1, the reinforcement rates were manipulated while the discrimination tasks did not vary. Which do chimpanzees prefer: a task providing a high reinforcement rate with high cognitive effort or a task providing a low reinforcement rate with low cognitive effort? The purpose of Experiments 2, 3, and 4 was to examine the nature of cognitive effort that may have an influence on choice behavior. In the three experiments, the cognitive effort was varied by manipulating the discrimination tasks.

Experiment 1

Experiment 1 examined whether the chimpanzee's choice depended more on the reinforcement rate or the cognitive effort. Previous studies have used response latencies, performance of secondary tasks, self-reports and so on in order to measure cognitive effort (Bettman, Johnson, & Payne, 1990). A few studies reported that the percentage of correct judgments was consistent with the self-reports of task difficulty (Bettman & Zins, 1979; Wright, 1975). Therefore, it is assumed in the present study that the difficulty of the discrimination tasks is reflected in the proportion of correct responses, which is in turn a measure of cognitive effort.

Increased cognitive effort in a task usually led to a decrease in the proportion of correct responses. Therefore, when the reinforcement schedule was kept constant, the discrimination task with a high cognitive effort had a low reinforcement rate. The reinforcement rate, however, can be separated from the proportion of correct responses by introducing different reinforcement schedules. Does the chimpanzee prefer the high reinforcement rate or the high proportion of correct responses? The reinforcement rates of the tasks were manipulated, although the tasks themselves were kept constant.

Figure 1. A subject performs a matching-to-sample task.

Method

Subject. The subject was a 12-year-old female chimpanzee named Pan, born at the Primate Research Institute, Kyoto University. Prior to this study, she had been involved in many experiments, including matching-to-sample tasks (Kojima, 1990; Kojima, Tatsumi, Kiritani, & Hirose, 1989; Tanaka, 1995).

Apparatus. Experimental sessions were conducted in an experimental room (approximately 180 cm × 180 cm × 180 cm) (Figure 1). The north and the south walls of the experimental room were symmetrical. A color monitor (NEC PC-KH2021) with a touch-sensitive panel (Micro Touch SMT2) was installed on each wall. A universal feeder (Biomedica universal feeder BFU-310) was placed above the monitor. It delivered the food reinforcers to a food tray installed under the monitor. The reinforcer used in the experiments was a slice of apple (about 1.0 g) or a raisin.

Procedure. Two different discrimination tasks were presented on the monitors installed in the north and the south walls. The discrimination tasks used in the present experiment were

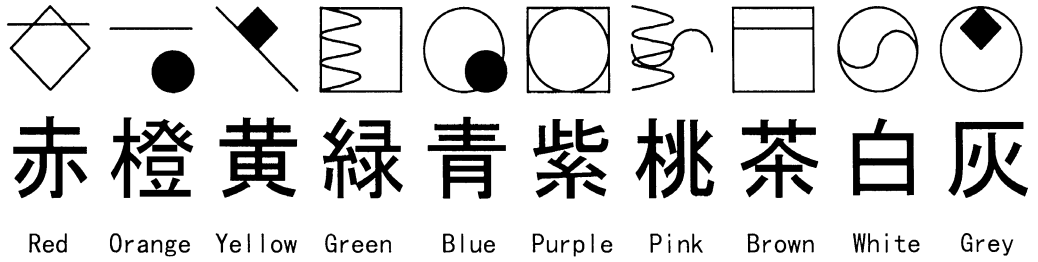

Figure 2. Ten lexigrams and 10 Chinese characters corresponding to the color stimuli.

identity matching-to-sample tasks with two alternatives. One task used Chinese characters as sample and comparison stimuli, and the other used complex geometric forms, called "lexigrams." Ten Chinese characters and 10 lexigrams were used. The stimuli corresponded to the colors red, orange, yellow, green, blue, purple, pink, brown, white, and grey (Figure 2). Chinese characters and lexigrams were the same as those used by Matsuzawa (1985a). A preliminary experiment had revealed that for the present subject the matching-to-sample task using lexigrams was less difficult than that using Chinese characters.

A trial proceeded as follows. At the beginning, a white circle approximately 5 cm in diameter appeared in the lower portion of the monitor as a "start key." After the chimpanzee touched the start key, the white circle disappeared and a sample stimulus appeared in the middle of the screen. After three touches of the sample stimulus, two comparison stimuli appeared in the upper right and left corners. If the chimpanzee chose the correct comparison, a chime sounded and a reinforcer was delivered. For the incorrect comparison, an error buzzer followed. Timeout after the error trials was 2 s, instead of delivery of the reinforcer in the correct trials. The intertrial interval was 2 s.

The matching-to-sample tasks using lexigrams and Chinese characters were presented on the north and south monitors, respectively. Each task consisted of 90 trials. A session ended only when the chimpanzee had completed both tasks: Therefore, the total amount of reinforcement in a session did not depend on her choice, but only on her correct responses. The order in which the chimpanzee performed the tasks was completely her choice. She could stop doing one task and change to the other. The monitors displaying the tasks and the sequence of presentation of the stimuli varied randomly across the sessions.

The present experiment consisted of three conditions, following an A–B–A design. Conditions 1 and 3 served as controls, in which both of the tasks delivered one reinforcer per one correct response. In condition 2 (experimental condition), however, the task using lexigrams delivered a reinforcer only after two correct responses occurred in succession. On the other hand, the task using Chinese characters delivered one reinforcer for every correct response. Each of the three conditions was in effect for 10 sessions.

Results and discussion

Proportion of correct responses. Table 1 shows the proportions of correct responses in the matching-to-sample tasks under conditions 1, 2, and 3. A Student's *t*-test could be applied to these data. In the three conditions, the proportions of correct responses of the tasks using lexigrams were significantly higher than those of the tasks using Chinese characters, $t(18) = 9.8$, $p < .0001$ in condition 1, $t(18) = 10.6$, $p < .0001$ in condition 2, and $t(18) = 8.73$, $p < .0001$ in condition 3. One-way analysis of variance revealed that there was no significant difference in the proportions of correct responses across the three conditions, $F(2, 27) = 2.5$, *ns*, with the lexigrams, and $F(2, 27) = .88$, *ns*, with the

Table 1. Proportions of correct responses, reinforcement rates, and priority indices in the matching-to-sample tasks in Experiment 1

Condition	Task	Proportion correct responses	RFT proportion	Priority index
1	Lexigram	.92 (.03)	.92 (.03)	.68 (.42)
	Chinese character	.70 (.06)***	.70 (.06)***	.32 (.42)
2	Lexigram	.94 (.04)	.45 (.03)	.31 (.26)*
	Chinese character	.68 (.06)***	.68 (.06)***	.69 (.26)
3	Lexigram	.89 (.06)	.89 (.06)	.58 (.18)
	Chinese character	.67 (.05)***	.67 (.05)***	.42 (.18)

RFT is reinforcement rate in task.
Standard deviations are in parentheses. Priority index indicates the degree to which the chimpanzee gave priority to the task. A value of 1 means that the chimpanzee maximally preferred the task.
Statistical analyses of proportion of correct responses and RFT proportion were conducted between tasks within the three conditions. Statistical analyses of priority indices were conducted across the conditions. The priority indices of the lexigram task in condition 2 were significantly lower than those in conditions 1 and 3.
*** $p < .0001$, * $p < .05$.

Chinese characters. The reinforcement rates were equal to the proportions of correct responses in conditions 1 and 3 but not in condition 2. In condition 2, the reinforcement rate of the task using Chinese characters was significantly higher than that of the task using lexigrams, $t(18) = 9.8$, $p < .0001$.

Priority index. The present study assumed that the chimpanzee would solve the preferred task prior to the less preferred task. Therefore, preference was measured based on the order in which the chimpanzee performed the tasks. The term "priority index" can be defined as a measure of the degree to which the chimpanzee gave priority to the solving of one task over the other. The priority indices were calculated as follows.

The first step was to allocate "priority points" to each of the tasks according to the order in which they were performed. Priority points allocated to the task solved in the first trial were 180. Thereafter, priority points decreased one by one as the trials proceeded. Second, the priority points were summed for each task within a session. Then, the priority index in the matching-to-sample task using lexigrams, for example, was calculated by the following equation.

$$\text{Priority index} = \{\text{Sum(l)} - \text{minimum point}\}/[\{\text{Sum(l)} - \text{minimum point}\} + \{\text{Sum(c)} - \text{minimum point}\}]$$

where Sum(l) and Sum(c) are the sum of the priority points for the task using lexigrams and Chinese characters, respectively. The minimum point was the sum of the points that were inevitably allocated to the task in order to complete a session.

This equation would indicate that the subject maximally preferred the matching-to-sample task using lexigrams when the priority index was equal to 1, and that the task was maximally aversive when the value was 0. When the priority index is 0.5, there is no difference in the subject's preference for the two tasks. In order to counterbalance position preference, each analysis dealt with data from two consecutive sessions.

The right-hand column of Table 1 shows the priority indices. The procedures of conditions 1 and 3 were identical. A Student's *t*-test revealed that there was no significant difference in the priority indices of conditions 1 and 3 in the task using lexigrams, $t(8) = .47$, *ns*. Therefore, a mean priority index from conditions 1 and 3 was calculated, the value of which was

.628 (SD = .298). A Welch's t-test revealed that the priority index of the task using lexigrams in condition 2 was significantly lower than in conditions 1 and 3, $t(10.15) = 2.27$, $p < .05$.

The present study manipulated the reinforcement rate while the discrimination tasks were held constant. Under such conditions, the cognitive effort was held constant throughout the experiment, since the proportions of correct responses did not vary. The results indicated that the chimpanzee's choice behavior depended on the reinforcement rate rather than the cognitive effort. In sum, when the reinforcement rates were proportional to the correct responses, the subject preferred the easier task providing a higher reinforcement rate. However, when the more difficult task provided a higher reinforcement rate, the subject preferred the task.

Experiment 2

In Experiment 2, the sample-choice relations were manipulated to vary the cognitive effort. A chimpanzee was exposed to a pair of matching-to-sample tasks in which the sample-choice relations were symmetrical. That is to say, the sample stimuli in the first task were comparison stimuli in the second task, and the comparison stimuli in the first task were sample stimuli in the second task. Preliminary studies had demonstrated consistent differences in proportions of correct responses between tasks in which stimuli had symmetrical relationships (Matsuzawa, Sato, & Suzuki, 1995). Experiment 2 examined the effect of cognitive effort on the chimpanzee's choice behavior produced by manipulating the sample-choice relations.

Method

Subject. The subject was a 19-year-old female chimpanzee, named "Ai," born in Africa and received in the laboratory at approximately 1 year of age. Prior to this study, she had been involved in many experiments, including matching-to-sample tasks (Fujita & Matsuzawa, 1990; Matsuzawa, 1985b, 1990; Tomonaga, 1995).

Apparatus. The apparatus in Experiment 2 was identical to that used in Experiment 1.

Procedure. The procedure of Experiment 2 was identical to that of Experiment 1 except for the following: Instead of identity matching-to-sample tasks, symbolic (i.e., arbitrary) matching-to-sample tasks were used in Experiment 2. Ten colors, 10 lexigrams, and 10 Chinese characters were used as stimuli. The lexigrams and the Chinese characters were identical to those used in Experiment 1.

Experiment 2 included two conditions. In one condition, colors and lexigrams were used (i.e., the lexigram condition), while in the other condition, colors and Chinese characters were used (i.e., the Chinese character condition). Daily sessions were conducted in either of the two conditions.

In Experiment 2, the two tasks that were presented on the north and the south monitors had symmetrical relations between samples and comparisons. For example, in the lexigram condition, one task on the north monitor used colors as sample stimuli and lexigrams as comparison stimuli. A second task on the south monitor used lexigrams as sample stimuli and colors as comparison stimuli. In the Chinese character condition, Chinese characters were introduced instead of the lexigrams. The chimpanzee received 20 sessions under each condition. The sessions using either of these two conditions were conducted in random order.

Results and discussion

Proportion of correct responses. Table 2 shows the proportions of correct responses for each task. In Experiment 2, each correct response was rewarded, so that the reinforcement rates were equal in the two tasks. Under both conditions, the proportions of correct responses in the task using colors as sample stimuli were significantly higher than when they were used as comparison stimuli, $t(38) = 14.5$, $p < .0001$; $t(38) = 14.5$, $p < .0001$, respectively.

Priority index. Priority indices were calculated as in Experiment 1. The priority indices are shown in the right-hand column of Table 2. Under both the lexigram and the Chinese character conditions, the priority indices differed

Table 2. Proportions of correct responses and priority indices in the matching-to-sample tasks in Experiment 2

Condition	Task	Proportion correct responses	Priority index
Lexigram	Color to lexigram	.95 (.03)	.56 (.14)
	Lexigram to color	.79 (.04)***	.44 (.14)*
Chinese character	Color to Chinese character	.92 (.04)	.61 (.21)
	Chinese character to color	.72 (.05)***	.39 (.21)*

Standard deviations are in parentheses. Reinforcement rates were equal to proportion of correct responses. In Experiment 2, the tasks between which the stimulus relations were symmetrical were presented. A priority index of 1 means that the chimpanzee maximally preferred the task.
Statistical analyses of proportion of correct responses and priority index were conducted within the conditions.
*** $p < .0001$, * $p < .05$.

significantly, $t(18) = 2.25$, $p < .04$, $t(18) = 2.38$, $p < .03$, respectively.

Thus, Experiment 2 manipulated sample-choice relations in order to vary cognitive effort. The chimpanzee was exposed to a pair of the matching-to-sample tasks, between which the stimulus relations were symmetrical. The subject's performance in color-sample tasks was better than that in the reversed tasks. However, the total amounts of reinforcement were independent of her choice. Nevertheless, there was clear preference for the tasks with higher proportions of correct responses and higher reinforcement rates.

Experiment 3

In Experiment 3, the number of the comparison stimuli in matching-to-sample tasks was manipulated to vary the cognitive effort. We increased the number of alternatives which the chimpanzee had to process. Studies of human decision making have reported that cognitive effort increased when the number of alternatives or their similarity increased (Cooper-Martin, 1993; Shugan, 1980; Tversky, 1977; Wright, 1975).

Method

Subject and apparatus. The subject and the apparatus were identical to those in Experiment 2.

Procedure. The procedure of Experiment 3 was identical to that of Experiment 2 except for the following: While one task had two comparison stimuli, the other task had 10 comparison stimuli. We provided two conditions, the lexigram condition and the Chinese character condition. Under both, the sample stimuli were always colors, and the comparison stimuli were either lexigrams or Chinese characters.

Results and discussion

Proportion of correct responses. Table 3 shows the proportions of correct responses. The reinforcement rates were again equal to the proportions of correct responses. In both the lexigram and the Chinese character conditions, the proportions of correct responses in the two-comparison task were significantly higher than those in the 10-comparison task, $t(18) = 7.22$, $p < .0001$, $t(18) = 39.4$, $p < .0001$, respectively.

Priority index. The right-hand column of Table 3 shows the priority indices. Under both the lexigram and the Chinese character conditions, the priority indices differed significantly, $t(18) = 8.49$, $p < .0001$, $t(18) = 328$, $p < .0001$, respectively.

In Experiment 3, the number of comparison stimuli were manipulated in order to vary cognitive effort. The task with the larger number of comparison stimuli produced lower proportions of correct responses. The chimpanzee preferred the task with two comparison stimuli

Table 3. Proportions of correct responses and priority indices in the matching-to-sample tasks in Experiment 3

Condition	Task	Proportion correct responses	Priority index
Lexigram	2 comparison stimuli	.98 (.01)	.85 (.18)
	10 comparison stimuli	.87 (.06)***	.15 (.18)***
Chinese character	2 comparison stimuli	.94 (.02)	.98 (.01)
	10 comparison stimuli	.54 (.04)***	.02 (.01)***

Standard deviations are in parentheses. Reinforcement rates were equal to proportion of correct responses. In Experiment 3, the tasks which differed in the number of comparison stimuli were presented. A priority index of 1 means that the chimpanzee maximally preferred the task.
Statistical analyses of proportion of correct responses and priority index were conducted within the conditions.
*** $p < .0001$, * $p < .05$.

to that with 10 comparison stimuli task, although the total amounts of reinforcement were independent of her choice. In summary, even if the nature of the discrimination tasks was identical, the chimpanzee preferred the task with less cognitive effort (i.e., two comparison stimuli as opposed to 10).

Experiment 4

In Experiment 4, the delay interval between the sample and the comparison stimuli was manipulated to vary the cognitive effort. The chimpanzee was exposed to a simultaneous matching-to-sample task and a delayed matching-to-sample task. In the simultaneous task, the chimpanzee was required to select comparison stimuli while the sample stimulus remained visible. However, in the delayed task, the sample stimulus was erased before the comparison stimuli appeared. The delayed matching-to-sample task has been used in order to examine short-term memory (e.g., Mackay, 1991). The present study examined the effects on the chimpanzee's choice of the cognitive effort derived from the need to memorize the sample stimuli.

Method

Subject and apparatus. The subject and the apparatus were identical to those in Experiments 2 and 3.

Procedure. The procedure of Experiment 4 was identical to that of Experiments 2 and 3 except for the following: In Experiment 4, the two tasks in any one condition differed with respect to the delay interval. The duration of the delay was 0 s: The comparison stimuli appeared immediately after the sample stimulus disappeared. Both tasks had two comparison stimuli as alternatives. It must also be noted that one of the two tasks in Experiments 2, 3, and 4 was identical, that is to say, a color-to-lexigram (or a color-to-Chinese character) symbolic simultaneous matching-to-sample task with two alternatives.

Results and discussion

Proportion of correct responses. Table 4 shows the proportions of correct responses in Experiment 4. The reinforcement rates were again equal to the proportions of correct responses. Under both the lexigram and the Chinese character conditions, there were no significant differences between the simultaneous and delayed matching in the proportions of correct responses, $t(38) = 1.42$, *ns*, $t(38) = .67$, *ns*.

Priority index. The right-hand column of Table 4 shows the priority indices in Experiment 4. In the lexigram condition, there was no significant difference in the priority index, $t(18) = .84$, *ns*. On the other hand, in the Chinese character condition, the priority index in the simultaneous matching-to-sample task

Table 4. Proportions of correct responses and priority indices in the matching-to-sample tasks in Experiment 4

Condition	Task	Proportion correct responses	Priority index
Lexigram	Simultaneous task	.98 (.01)	.56 (.33)
	Delayed task	.97 (.02)	.44 (.33)
Chinese character	Simultaneous task	.95 (.03)	.67 (.24)
	Delayed task	.94 (.02)	.33 (.24)**

Standard deviations are in parentheses. Reinforcement rates were equal to proportion of correct responses. In Experiment 3, the tasks which differed in the number of comparison stimuli were presented. A priority index of 1 means that the chimpanzee maximally preferred the task.
Statistical analyses of proportion of correct responses and priority index were conducted within the conditions.
** $p < .01$.

was significantly higher than that in the delayed task, $t(18) = 3.27$, $p < .01$.

The delayed matching-to-sample task is assumed to require more cognitive effort because of the need to memorize the sample stimuli. In the lexigram condition, there was no difference in the proportions of correct response and the subject showed no preference. However, in the Chinese character condition the simultaneous matching-to-sample task was preferred to the delayed task despite the lack of significant differences in both the proportions of correct response and the reinforcement rate.

General discussion

The purpose of the present study was to investigate the effect of cognitive effort on the chimpanzee's choice behavior between the discrimination tasks. Experiment 1 showed the chimpanzee choosing a task in spite of its greater cognitive effort; the chimpanzee preferred to do a cognitively difficult task provided that its reinforcement rate remained higher than that of the other tasks. In Experiments 2, 3, and 4, we influenced the chimpanzee's choice by varying the cognitive effort. These experiments manipulated the following three variables: the sample-choice relations in matching-to-sample tasks, the number of comparison stimuli, and the delay interval between the sample and the comparison stimuli.

In Experiments 2 and 3, the chimpanzee preferred the task with the higher proportion of correct responses and reinforcement rate. In these experiments, the effects of the cognitive effort were confounded with those of the reinforcement rate. However, it must be noted that the total amounts of reinforcement were independent of the choice. A session ended only when the chimpanzee had completed both tasks, regardless of the choice between the two. Therefore, the results indicated that the chimpanzee was sensitive to the local change of reinforcement rate in choosing between the two discrimination tasks.

On the other hand, in Experiment 4, despite the lack of apparent difference in the proportion of correct responses and the reinforcement rate, the chimpanzee preferred the simultaneous matching-to-sample task to the delayed task under one of the two conditions. Even in the absence of a difference in the proportion of correct responses and reinforcement rate in the two tasks, the chimpanzee preferred the task that was assumed to require the less cognitive effort. Through Experiments 2, 3, and 4, the matching performance in the Chinese character condition was inferior to that in the lexigram condition in general. This means that the cognitive effort in the Chinese character condition was higher than that in the lexigram condition, and seems to result in the significant difference in the effect of delay in Experiment 4.

Studies of choice behavior using reinforcement schedules as alternatives have demonstrated that preference depends on reinforcement rate. The present study, using discrimination tasks as alternatives, also indicated that the reinforcement rate has great influence over a chimpanzee's preference. It also indicated, however, that preference also depends on the nature of the discrimination task, even if the reinforcement rates are identical. The results cannot be explained by the hypotheses proposed in previous studies of physical cost (lever pressing in rats, or key pecking in pigeons) such as the matching law (Baum, 1979; Herrnstein, 1961) and the delay reduction hypothesis (Fantino, 1969). These hypotheses agreed with the proposition that the magnitude of preference should be proportional to the ratio of the reinforcement rates. They do not address changes in preference independent of the reinforcement rate.

The present study demonstrated that the chimpanzee's choice behavior depended on cognitive effort in addition to the reinforcement rate. It also indicated that the following variables influenced cognitive effort: the reversal of the sample-choice relationship, the increase in the number of comparison stimuli, and the introduction of delay. All these variables were effective in inducing cognitive effort sufficient to lead to a change in choice preference, but especially the introduction of delay, although it did not result in a change of the reinforcement rate. Further studies will focus on quantitatively evaluating other variables capable of inducing cognitive effort in nonhuman animals.

References

Baum, W. M. (1979). Matching, undermatching and overmatching in studies of choice. *Journal of the Experimental Analysis of Behavior*, **32**, 269–281.

Bettman, J. R., & Zins, M. (1979). Information format and choice task effects in decision making. *Journal of Consumer Research*, **6**, 141–153.

Bettman, J. R., Johnson, E. J., & Payne, J. W. (1990). A componential analysis of cognitive effort in choice. *Organizational Behavior and Human Decision Processes*, **45**, 111–139.

Cooper-Martin, E. (1993). Effects of information format and similarity among alternatives on consumer choice processes. *Journal of the Academy of Marketing Science*, **3**, 239–246.

Fantino, E. (1968). Effects of required rates of responding upon choice. *Journal of the Experimental Analysis of Behavior*, **11**, 15–22.

Fantino, E. (1969). Choice and rate of reinforcement. *Journal of the Experimental Analysis of Behavior*, **12**, 723–730.

Fujita, K., & Matsuzawa, T. (1990). Delayed figure reconstruction by a chimpanzee (*Pan troglodytes*) and humans (*Homo sapiens*). *Journal of Comparative Psychology*, **104**, 345–351.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, **4**, 267–272.

Kojima, S. (1990). Comparison of auditory functions in the chimpanzee and human. *Folia Primatologica*, **55**, 62–72.

Kojima, S., Tatsumi, I. F., Kiritani, S., & Hirose, H. (1989). Vocal-auditory functions of the chimpanzee: consonant perception. *Human Evolution*, **4**, 403–416.

Mackay, H. A. (1991). Conditioned stimulus control. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior* (pp. 301–350). Amsterdam: Elsevier Science.

Matsuzawa, T. (1985a). Colour naming and classification in a chimpanzee (*Pan troglodytes*). *Journal of Human Evolution*, **14**, 283–291.

Matsuzawa, T. (1985b). Use of numbers by a chimpanzee. *Nature*, **315**, 57–59.

Matsuzawa, T. (1990). Form perception and visual acuity in a chimpanzee. *Folia Primatologica*, **55**, 24–32.

Matsuzawa, T., Sato, A., & Suzuki, S. (1995). Color recognition in a chimpanzee: The study by an identity matching-to-sample task and a symbolic matching-to-sample task. *Japanese Journal of Animal Psychology*, **45**, 138 (in Japanese).

Russo, J. E., & Dosher, B. A. (1983). Strategies for multiattribute binary choice. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **9**, 676–696.

Shugan, S. M. (1980). The cost of thinking. *Journal of Consumer Research*, **7**, 99–111.

Tanaka, M. (1995). Object sorting in chimpanzees (*Pan troglodytes*): Classification based on physical identity, complementarity and familiarity.

Journal of Comparative Psychology, **109**, 151–161.

Tomonaga, M. (1995). Visual search by chimpanzees (*Pan troglodytes*): Assessment of controlling relations. *Journal of the Experimental Analysis of Behavior*, **63**, 175–186.

Tversky, A. (1977). Attributes of similarity. *Psychological Review*, **84**, 327–352.

Wright, P. (1975). Consumer choice strategies: Simplifying vs. optimizing. *Journal of Marketing Research*, **11**, 60–67.

(Received August 31, 1996; accepted March 15, 1997)