A New Procedure to Study the Perceptual World of Animals with Sensory Reinforcement: Recognition of Humans by a Chimpanzee

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ABSTRACT. A female chimpanzee touched a button to produce colored slides of pictures. Slides were present as long as she kept touching the button. Repeated touch within 10 sec after the previous release produced the same slides again. The slide was changed when 10 sec passed after she released the button. The duration of a touching response and the interval between the responses were calculated for each of 100 slides. The data for each slide were plotted on the two-dimensional space constructed with response duration and response interval. A clear differentiation of distribution on this space was found between slides with humans and those without humans. The result demonstrated that the chimpanzee recognized humans as a category, as well as that this procedure is effective for the study of the perceptual world of animals based on the reinforcing function of stimuli.

Key Words: Perceptual world; Sensory reinforcement; Conjugate reinforcement; Visual preference; Key touch; Chimpanzees.

INTRODUCTION

How do animals distinguish and categorize animate or inanimate objects surrounding them? The study of such aspects of the perceptual world of animals and its ontogenetic changes is of great interest in and of itself. In addition, such knowledge may allow for behavioral investigations of the phylogenetic relationships among close species.

One approach to the perceptual world of animals, which is commonly used in psychophysical studies with nonhuman animals (e.g., STEBBINS, 1970), is to analyze discriminative function of stimuli on operant responses. This is accomplished by analyses of learning and generalization processes of discrimination performances. For example, in a series of studies, HERRNSTEIN and his colleagues trained pigeons to form several kinds of natural concepts. They found that pigeons formed a concept of a particular person more easily than a concept of the Charlie Brown character of the cartoon comic strip, *Peanuts* (HERRNSTEIN & DEVILLIERS, 1980). They suggested that these results were obtained because pigeons recognized pictures of a real person as a category but not pictures of a cartoon character. SANDS et al. (1982) trained rhesus monkeys in a kind of matching-to-sample task with a variety of pictures. They analyzed the resulting confusion matrices using a multidimensional scaling procedure. The analyses revealed that the monkeys recognized the pictures of human and monkey faces, those of fruit, and those of flowers as separate groups. Although this type of approach may be powerful in identifying the critical features that define a category, it is only applicable to those animals who are able to master the task after a considerably long period of training.

The second and a more convenient approach is to analyze reinforcing function of stimuli.

SACKETT (1970) measured the duration of orientation and approach responses of monkeys to live animals. He demonstrated that infant monkeys oriented and approached adult animals of their own species for longer duration than adult animals of different species. SWARTZ (1983) measured the duration of visual fixation as an index. After repeated exposure to one picture, a new picture is presented. The amount of recovery of visual fixation to the new stimulus is assumed to reflect the discriminability of the two stimuli for the subject. With this "habituation-dishabituation" procedure, she showed that young pigtail macaques discriminated pictures of three macaque species. Although these procedures do not require any training periods, the responses chosen as an index are not well-defined operants and are difficult to measure. In addition, the stimuli that can be tested may be limited to those that cause such natural responses as orienting or gazing.

These shortcomings are easily corrected by the introduction of any artificial operant response, such as leverpressing. HUMPHREY (1974) trained rhesus monkeys to press a lever to obtain food. The subjects were also allowed to see a picture for the duration of the leverpress. The stimuli were presented according to the "habituation-dishabituation" technique. The amount of recovery of the holding response suggested that the rhesus monkeys discriminated individual monkeys. SWARTZ and ROSENBLUM (1980) trained bonnet macaques to press a switch to see videotaped images of a monkey. The same stimulus was repeatedly presented during periods of at least 15 min. The duration of pressing response for conspecific animals was longer than that for animals of different species. Thus the visual discrimination of different species was demonstrated. MATSUZAWA and FUJITA (1981) reported a new procedure to measure the reinforcing power of visual stimuli. Periods in which leverpressing responses resulted in a visual stimulus alternated with periods in which no visual stimulus resulted. The relative time allocation of leverpressing for these two periods was a consistent index of the reinforcing power of the visual stimulus. MATSUZAWA (1981) applied this procedure to the study of color perception of Japanese monkeys by measuring relative reinforcing power of various colored lights through Wratten filters. He demonstrated that 1-year-old monkeys perceived colored lights based on two dimensions, namely hue and brightness. The above procedures have in common the advantage that a long-term training is unnecessary. However, all these procedures used only the total duration of responses as the index of the reinforcing power of the stimuli. That is, the stimuli have been evaluated on the unidimension of the reinforcing value. Two stimuli that cause the same total duration of responses do not necessarily have equivalent frequency distributions and/or average durations. The analysis of such temporal distribution of responses might suggest non-unidimensional reinforcing nature of the stimulus.

In the present experiment, we proposed two indices to measure the reinforcing nature of the stimuli: the duration of responses and the interval of responses. These two indices define the characteristic features of the temporal distribution of responses. We report here a new convenient procedure to study the perceptual world of animals by assessing the reinforcing nature of a variety of stimuli with these two measures. The results of a preliminary study with a chimpanzee are reported.

METHOD

SUBJECT

A 7-year-old female chimpanzee named *Ai* served as subject. She had a long training history of artificial language (see ASANO et al., 1982; KOJIMA, 1984; MATSUZAWA, 1985a, b). On weekdays, she served as a subject for other experiments or played with other chimpanzees during daytime, and was back into the individual cage at about 4:00 p.m. On holidays, she was in her cage all day long.

APPARATUS

A transportable testing apparatus, which consisted of the response panel and the controlling box, was attached to the chimpanzee's home cage. The response panel had a touch key (33 mm in diameter) and a small red lamp (15 mm in diameter). This lamp was located 2 cm below the key. A 35-mm slide projector with a rotary magazine for 100 slides and an opaque screen were put on the controlling box. The screen was located at about 1 m distant from the response panel. A microcomputer (EPSON HC-20) installed in the box controlled the equipment and recorded the data. Other input/output devices are also installed in the box.

STIMULI

The following eight sets of ready-made colored slides produced by SK Color Company were used: No. 31: Kabuki (a Japanese classical drama); No. 38: Beautiful 'Maiko' (a Geisha girl); No. 42: The Ginza in Tokyo; No. 52: Japanese gardens (2); No. 103: Sumo (a Japanese wrestling) and Judo; No. 109: The Japanese castles; No. 111: The aerial views of Tokyo; No. 124: Mt. Fuji in the four seasons. These slides, usually sold to travelers in souvenir shops, are to introduce Japan to foreigners. Each set had ten different slides of the topic. Thirty-nine slides out of 80 included one or more humans that were easily identifiable (larger than 1.5 cm per person on the screen) and 34 slides did not. These two groups are later referred to as "Human" slides and "No human" slides. The remaining seven slides included humans but the images were very small (smaller than 1.5 cm on the screen). This group is later referred to as "Ambiguous" slides. In addition to these, two sets of slides (ten slides each) were used. One was simple light (no film on the slide mount) and the other was no light (black paper on the film). These 100 slides were inserted in quasi random order in the rotary magazine. The slides were projected with the size 35×23 cm on the screen.

PROCEDURE

The experiment started immediately after the touching response on the key was molded. When the red lamp was on, a touch on the key produced a picture on the screen (i.e., sensory reinforcement. See KISH, 1966; FOWLER, 1971). The slide was present as long as the subject kept touching the key; that is, a conjugate reinforcement schedule (see ROVEE-COLLIER & GEKOSKI, 1979) was used. The picture disappeared when the subject released the key. Touching response within 10 sec after the subject released the key produced the same stimulus repeatedly. When 10 sec passed without touching after the subject released the key, the slide was changed to the next one (i.e., the rotary magazine was rotated by one slide). The next touching response produced this new slide on the screen. Slides were never changed until at least one touching response was made for the slide. That is, the subject had to see each slide at least once. Figure 1 shows the contingency in a diagram. As is shown in Figure 1, intervals between the onset of the first response for the slide and change of the slide is referred to as a "trial." With this procedure, the subject was able to see the same stimulus as long as desired

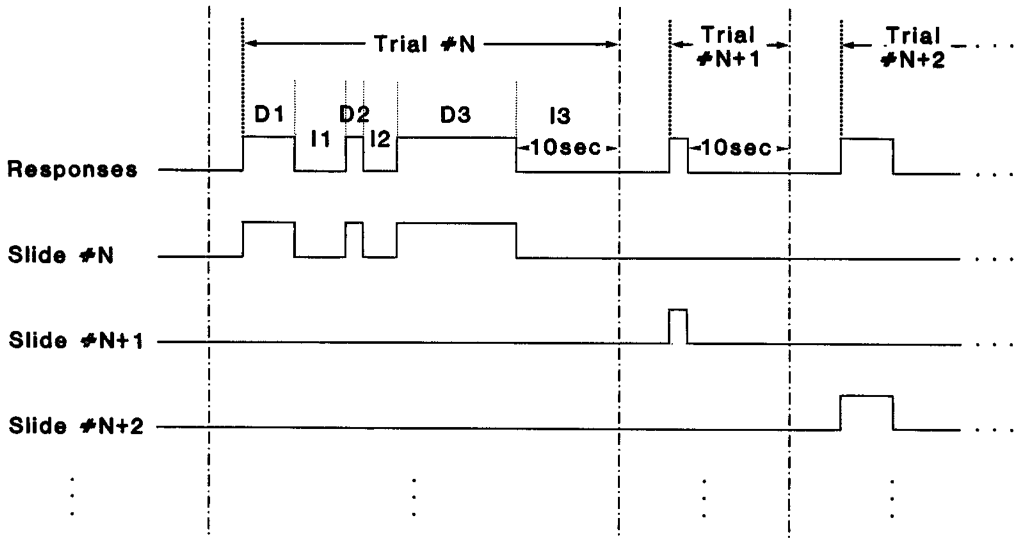

Fig. 1. A diagram of the experimental procedure. D: Duration of responses; I: interval between responses.

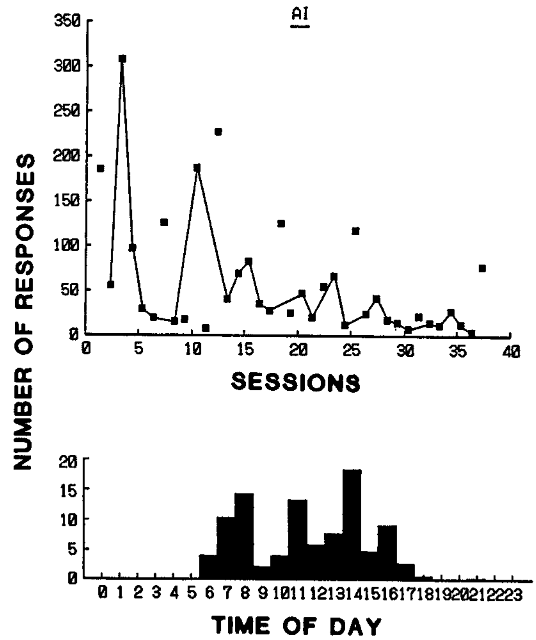

Fig. 2. Upper column: The number of responses in all sessions of the experiment. The data for sessions having a duration of 16.5 hrs (from 4:30 p.m. to 9:00 a.m.) are connected. Lower column: Circadian rhythms of touching responses to see pictures. The number of responses per hour was shown.

by maintaining a key touch and was able to see the stimulus as many times as desired by touching the key again before 10 sec elapsed.

On every trial, the number of responses, sum of the duration of touching responses (e.g.,

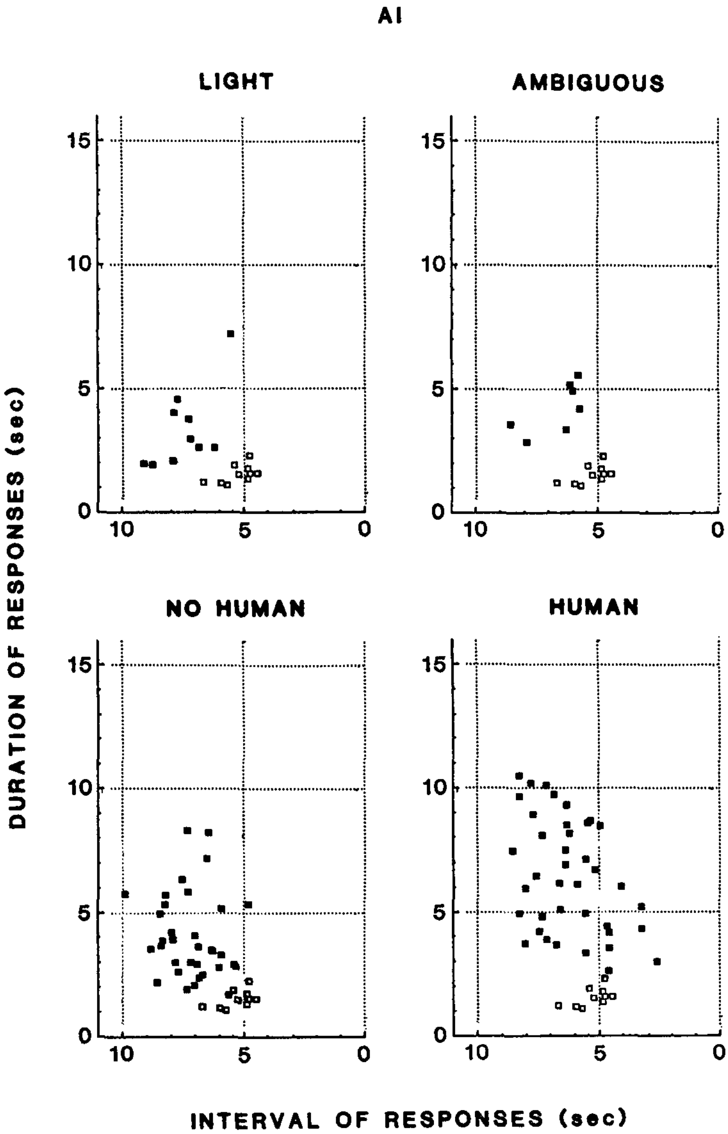

Fig. 3. Resulting two-dimensional distribution of the individual slides located with the duration of responses for the slide (vertical axis) and the interval of responses for it (horizontal axis). Every symbol designates individual slides. Control slides (i.e., no light) are shown in unfilled symbols on each graph.

D1+D2+D3+ in Fig. 1) and sum of the interval between release and the following touch or change of slide (e.g., I1+I2+I3 in Fig. 1) were recorded. The length of each session was not constant. Most of the sessions started at 4:30 p.m. and ended at 9:00 a.m. on the next day. On holidays, sessions continued throughout daytime until the morning of the next working day. During sessions, people were not restricted from entering the cage room. The experiment was continued until the subject completed 1,000 trials (i.e., 10 trials for each slide). That is, it finished after 10 cycles of the rotary magazine.

RESULTS

Thirty-seven sessions were necessary until the subject completed 1,000 trials. The upper column of Figure 2 shows the number of touching responses in all sessions. The connected lines show the data for the sessions that started at 4:30 p.m. and ended at 9:00 a.m. on the next day. The data plotted off the lines show those obtained in sessions that had different durations. The number of responses gradually decreased as sessions repeated. The lower column of Figure 2 is the circadian rhythm of touching responses. Two major peaks of responses, one in the morning and the other in the afternoon, were observed. These results show there was a long-term change in the response rates. But as these changes are canceled out throughout the experimental period, the data for the ten trials of each individual slide were summed up.

The mean duration of touching response and the mean interval between release and touch were calculated for the individual slides. The data for each slide was located on the two-dimensional space constructed with the duration (D) and the interval (I) of the touching response. Figure 3 shows the results for the four groups of slides (filled symbols) with control slides of no light (unfilled symbols). The vertical axis shows the duration and the horizontal axis shows the interval in seconds. Note that the value of the interval was ordered from right to left. On the D-I space, "preferred" slides, namely slides with long durations and short intervals, are located on the upper-right position. Every symbol designates the individual slides.

The control slides ("No light") were distributed in a unique area on the D-I space compared with other slides. They had very short durations and intervals. The short intervals seem to be a consequence of temporary extinction of the response because the touching response never caused visual stimuli in the control condition. Slides with humans distributed on an upper-right position in comparison with all other groups. It is obvious that the subject preferred pictures with humans. "Human" slides and "No human" slides distributed in clusters having their centers at different positions. The distribution of the slides of other three groups, "Light," "Ambiguous," and "No human," had a considerable overlap.

The Multivariate Analysis of Variance (MANOVA) was conducted on every combination of five groups. As the numbers of observations were different between groups, the General Linear Model (GLM) procedure was used. F approximation was made by Hotelling-Lawley Trace. The results of this statistical test are summarized in Table 1. The test revealed the significant differences in the resulting two-dimensional distribution between "Human"

Table 1. The results of MANOVA based on the response duration and the response interval.

	Human	Ambiguous	No human	Light	No light
Human	—	$p<0.05$	$p<0.001$	$p<0.001$	$p<0.001$
Ambiguous	4.37 ($df = 2, 43$)	—	ns	ns	$p<0.001$
No human	23.77 ($df = 2, 70$)	0.67 ($df = 2, 38$)	—	ns	$p<0.001$
Light	15.02 ($df = 2, 46$)	1.16 ($df = 2, 14$)	0.88 ($df = 2, 41$)	—	$p<0.001$
No light	20.24 ($df = 2, 46$)	83.48 ($df = 2, 14$)	20.64 ($df = 2, 41$)	47.31 ($df = 2, 17$)	—

The upper part of the diagonal represents the probability and the lower part of the diagonal represents the F value.

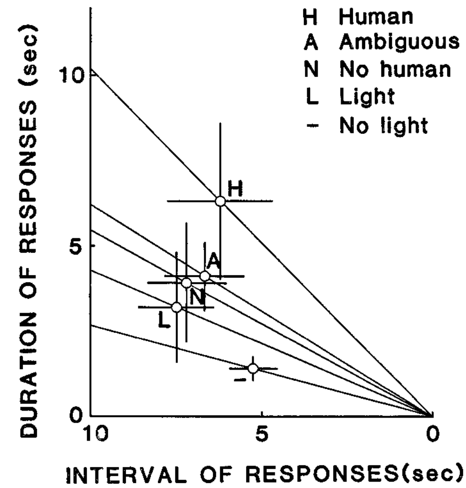

Fig. 4. The centers of distribution for the slides of each groups (i.e., group mean of durations and intervals) are shown. Standard deviations of the durations and intervals of the groups are shown in the vertical and horizontal lines. See text for other details.

slides and those of all the other groups. The distribution of the "No light" slides was also significantly different from those of all the other groups. Other combinations were not significant.

In order to compare the preference among five groups, the centers of the distribution (i.e., the group mean of durations and intervals) for the five groups of stimuli and the standard deviations are shown in Figure 4. Each data point was connected to the origin by a diagonal line. It should be noted that any point on the diagonal line coming from the origin has the same total response duration per a fixed time. The steeper the line is, the longer the total response duration is. Therefore the order of preference is shown by the inclination of these lines. In this experiment, the order of preference was: "Human," "Ambiguous," "No human," "Light," and No light," although the distributions of intermediate three categories were not significantly different.

DISCUSSION

A significant differentiation of the distribution of each slide was found between human slides and no human slides. They distributed in two different clusters on the D-I space. The result suggests that the chimpanzee recognized a variety of human pictures that had great differences in size, number, clothes, identity, etc. as a category. Herrnstein and deVilliers (1980) demonstrated that pigeons recognized a variety of pictures of a particular person as a category, after intensive training with a huge number of pictures of the person. We suggest that such long-term training may be unnecessary, at least in some cases, for the investigation of the perceptual world of animals and that the simple procedure proposed in this study is really effective for it. Second, the strong preference for the pictures of humans was observed. This shows that the pictures of humans have a strong reinforcing property for this subject. This might be resulted from the fact that this subject has been kept by humans for a long time. Humphrey (1974) demonstrated that monkeys who first did not distinguish individual animals of several domestic animals came to discriminate them as a result of repeated exposure of the stimuli. It would be interesting to know whether wild chimpanzees show the same preference as our subject.

We suggest here advantages of the proposed procedure. First, the procedure requires neither long-term discrimination training nor any food deprivation. Only a very simple operant response such as touching a key is necessary. This enables us to study the perceptual world of young animals as well as that of adult animals. With this procedure, we are able to investigate early phases of ontogenetic change of the perceptual world. Second, in addition to such a convenience, it is possible to detect the critical features that define a category, as is possible with procedures which analyze discriminative function of stimuli after intensive training, because we can test a variety of stimuli at once. This will be accomplished by testing with systematically modified stimuli. Finally, as the reinforcing properties of stimuli are measured with two variables, the duration and the interval of responses, the two stimuli that have the same total duration of responses at a look (i.e., the same strength of preference) can be differentiated by the detailed analysis of their two-dimensional distribution on the D-I space. For example, in Figure 4, the total response duration (the inclination of the line on the figure) for "Light" was not very different from that for "No light" slides. But since these two groups of slides have a large difference in the interval of responses, MANOVA detected a highly significant difference between these two groups (see Table 1). Although the factors that define the duration and the interval of the operant response for the stimulus are still unknown, this procedure enables us to evaluate the reinforcing nature of stimuli on the multidimensional scale rather than the traditional unidimensional scale. It might be fruitful to study the perceptual world of animals based on multidimensional scaling of stimuli.

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