STIMULUS DEFINITION IN CONDITIONAL DISCRIMINATIONS

IVER H. IVERSEN, MURRAY SIDMAN, AND PHILIP CARRIGAN

NORTHEASTERN UNIVERSITY

With a customary arrangement of three horizontally aligned stimulus/response keys, two rhesus monkeys learned conditional hue and line discriminations—an “identity-matching” procedure. First, sample stimuli were always presented on the center key, and comparison stimuli were presented on the two side keys. Next, the sample was allowed to appear on any one of the three keys, with the comparisons on the remaining two. The change from fixed to variable sample and comparison locations caused the horizontal and vertical lines to lose control over the animals’ responses; the conditional line discrimination deteriorated. This was not true for the red and green hues; the conditional hue discrimination remained intact. Accurate description of controlling stimuli in a matching-to-sample procedure may therefore require that their spatial location be specified.

Key words: conditional discrimination, matching to sample, stimulus definition, stimulus control, rhesus monkeys

One conditional-discrimination procedure, sometimes called matching to sample, requires a subject to select one of a set of comparison stimuli in the presence of a particular sample stimulus, and to select other comparison stimuli in the presence of different samples. For example, with three keys arranged in a row, a trial may begin with the center key illuminated either red or green. When the subject presses this sample, the two side keys are also illuminated, one red and the other green. The reinforcement contingencies require the subject to press the comparison stimulus—the side key—that has (for the experimenter) the same color as the center key.

In this instance, specification of the controlling stimuli as hues might, of course, be incorrect; the red and green stimuli may, for example, also differ in brightness. If the stimuli were geometric forms, various small details of the forms like angles, curvatures, line

lengths, etc., rather than the overall shape, might constitute the effective stimuli for different subjects. Sometimes, errors in defining the stimuli are of little or no consequence. When, however, one is concerned with the transfer of stimulus control, as in studies of stimulus generalization, concept formation, or stimulus equivalence, incorrect specification of the controlling stimuli will almost inevitably lead to incorrect or, at best, tentative interpretations of the data.

A possible source of unspecified control in the usual experimental arrangement for studying conditional discrimination is the spatial location of sample and comparison stimuli. As in the example described here, it is common laboratory practice with a variety of subjects to use three stimulus/response keys, with sample stimuli always presented on the same key, and comparison stimuli always presented on the other two keys. Implicit in this practice is the assumption that these consistent spatial locations are irrelevant to the definition of the effective stimuli. To validate this assumption would require that a subject respond to a stimulus in the same way regardless of the key on which the stimulus was presented. If a subject’s matching-to-sample performance does not survive changes in the placement of sample and comparison stimuli, then spatial location will have to be specified when identifying the controlling aspects of the stimuli.

Unpublished experiments with several

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species of nonhuman subjects in this laboratory had raised a suspicion that the sample and comparison functions of particular stimuli are specific to their spatial locations. We tested this possibility in the present experiment by first training rhesus monkeys in the customary "identity-matching" procedure with sample and comparison stimuli occupying fixed positions in a three-key display. We then varied the location of the stimuli so that samples and comparisons could appear on any of the three keys. Would the animals now continue to perform accurately?

METHOD

Subjects

The subjects were 2 adult rhesus monkeys, *Macaca mulatta*. They were fed at fixed times, enough to maintain their weights as near as possible to free-feeding levels. An animal that did not obtain its full ration in an experimental session received the remainder 1 hr after returning to its home cage. Both animals had previously received extensive training with hue and line stimuli in conditional-discrimination procedures in a different apparatus, with approximately equal exposures to hue and line stimuli.

Apparatus

The experimental chamber was housed in a sound-attenuating, fan-ventilated cubicle located in the same room as the programming and recording equipment. The chamber was 63 cm high, 61 cm wide, and 59 cm deep. One stainless-steel wall, opposite the access door, contained three stimulus/response keys, a houselight, and three food-pellet dispenser trays, each 4 cm above a key. Each key was 2.7 cm in diameter; a press on the key operated a limit switch. The keys were aligned horizontally 42 cm above the chamber floor, with a center-to-center distance of 4.5 cm. The center of the middle key was at the vertical midline. (A fourth key, 9.5 cm below the center key, was not used in the experiment.) An IEE projector (Grason Stadler #A509-2A, stimulus pattern 156) behind each key provided the stimuli, red or green patches filling the key, or a vertical or horizontal white line, 0.3 by 1.8 cm, on a black background.

Each pellet tray was connected via a chute to a separate pellet feeder, which delivered

Noyes 1-g banana pellets. This arrangement ensured that pellets produced by responses on a given key were delivered directly above that key.

A 60-W Sylvania Lumiline houselight, protected by an aluminum grill, was mounted above the row of keys, its top 55 cm above the floor. A DEC LSI-11 computer controlled sequences of stimuli and experimental procedures. An Esterline 20-pen event recorder was used on occasion to record events of interest.

Procedure

General procedures. Because the subjects had extensive experience with conditional discriminations, they needed no preliminary training on the procedural sequence. All trials began with a sample stimulus appearing on one of the three keys. By pressing this sample key, the subject produced comparison stimuli on the two remaining keys. The sample stimulus stayed on. Then, a press on the comparison key that displayed the same stimulus as the sample key produced delivery of one food pellet. If the animal pressed the comparison key that had a nonmatching stimulus, the trial ended without a food pellet. Pressing the nonmatching stimulus did not cause the trial to be repeated; the procedure was noncorrectional. The animal produced no programmed consequence by pressing a blank comparison key after a sample had appeared, or by pressing the sample key again after stimuli had appeared on the comparison keys. During the intertrial interval that followed each trial, all keys were blank. Whenever the animal pressed any blank key between trials, the intertrial interval restarted. The intertrial duration was 30 s for Monkey R47 and 60 s for Monkey R50.

On hue trials, the animals' task was to select the comparison key that displayed a hue identical to the sample key (red if the sample was red; green if the sample was green). Similarly, on line trials, the subject had to select the comparison line that was identical to the sample (vertical if the sample was vertical; horizontal if the sample was horizontal).

Each combination of stimuli and keys occurred equally often, with the restriction that every possible stimulus/key configuration (e.g., red sample on Key 2, red comparison on Key 1, and green comparison on Key 3) had to occur once in a block of trials before any con-

figuration was repeated. With that exception, all trial configurations and correct keys were equally probable on successive trials. The program arranged a sequence of 192 to 254 trials. For each monkey, a session began with the trial that would have come up next at the end of that animal's previous session. The number of pellets delivered per session was usually held constant at 120 for Monkey R47 and 100 for Monkey R50. Therefore, trials per session varied with the percentage of correct responses.

Baseline and moving sample. In the baseline procedure, the sample always appeared on the center key and the comparison stimuli on the two side keys. In the moving-sample procedure, the sample could appear on any of the three keys, and did so from trial to trial in a pseudorandom sequence. As in baseline, a press on the sample key produced comparison stimuli on the two remaining keys while the sample key remained on. Because the sample position changed from trial to trial, the comparison stimuli, of necessity, also changed; whenever a sample appeared on a side key, then one of the comparison stimuli had to appear on the center key, a spatial location not used for comparison stimuli in the baseline condition.

Table 1 summarizes the sequence of baseline and moving-sample conditions for each subject. The animals had to meet a 95% accuracy criterion on at least two consecutive baseline sessions before being shifted to the moving-sample procedure. Monkey R47's first three conditional hue-discrimination baseline sessions were followed by two moving-sample sessions, also made up only of hue trials. Next, after baseline training on the line discrimination alone (47 sessions), the animal had one moving-sample session that was made up only of line trials. Then, after two baseline sessions that included both hue and line conditional discriminations in mixed order, the subject had 12 moving-sample sessions with mixed hue and line trials. Finally, hue trials were removed, and moving sample was continued for 48 more sessions with only line trials.

For Monkey R50, the moving-sample procedure was not introduced until the subject had met criterion on both the hue and line conditional discriminations. After two sessions of only hue trials, the subject had 26 baseline training sessions that included only line trials.

Table 1

The sequence of experimental conditions for each monkey, showing sample-key location, stimuli, and number of sessions. The sample appeared either on Key 2 (baseline procedure) or on any of Keys 1, 2, or 3 (moving-sample procedure).

Sample keys	Stimuli	Sessions
Monkey R47		
2	hues	3
1, 2, 3	hues	2
2	lines	47
1, 2, 3	lines	1
2	hues, lines	2
1, 2, 3	hues, lines	12
1, 2, 3	lines	48
Monkey R50		
2	hues	2
2	lines	26
2	hues, lines	5
1, 2, 3	hues, lines	1
1, 2, 3	lines	7

The next five baseline sessions mixed both kinds of trials. Then, moving sample was introduced for one session with both hue and line trials, and, finally, was continued for seven sessions of only line discriminations.

RESULTS

The effect of the change from fixed position to moving samples depended on the stimuli. Figure 1 presents the percentages of correct trials separately for conditional hue and line discriminations during the last baseline session and the first moving-sample session. Baseline performances were nearly perfect for both types of stimuli. With hues, the animals' experience with the sample always in the center sufficed to bring about an immediate transfer of control to samples at new key positions, the moving-sample hue trials remaining nearly 100% correct for both subjects. The hues, therefore, retained their sample and comparison functions independently of the keys on which sample and comparison stimuli appeared.

In contrast to its lack of effect on the hue discrimination, the moving-sample procedure disrupted both subjects' line discriminations, Monkey R47's overall accuracy decreasing to 73% and Monkey R50's to 66%. The lines, therefore, did not retain their sample and comparison functions when the sample and

Fig. 1. Percentage of correct trials in conditional hue and line discriminations when the sample always appeared on Key 2 (baseline) or on any of the three keys (moving sample). Data are from the last session of baseline and the first session of moving sample. For Monkey R47, hue and line discriminations were tested separately (see Table 1). For Monkey R50, trials with both discriminations occurred in mixed order within sessions.

comparison locations varied among the three keys.

A more detailed analysis of the disrupted line discrimination shows even the seeming remnants of conditional control (the differences between the observed overall accuracies and the chance level of 50%) to be illusory. A given trial could belong to one of three classes,

defined by the stimulus configuration facing the animal immediately after it had pressed the sample, and by the prevailing reinforcement contingencies. Figure 2 illustrates the 12 possible kinds of trials in the moving-sample procedure.

The leftmost set of four displays constitutes one class, with the sample always occupying the center position (Key 2). Although presented during moving-sample sessions, these configurations and their associated reinforcement contingencies were the same as those in effect during baseline; the subject could produce a food pellet by pressing whichever *side key* showed the same line as the *center-key* sample. Such trials are therefore termed "baseline" trials.

In the center set of four displays, the sample is on side Key 1, and in the rightmost set is on side Key 3. The upper two configurations in these sets (VVH and HHV for Key 1 samples, and VHH and HVV for Key 3 samples) were the same as the four baseline displays, but involved different contingencies; the subject could produce a food pellet only by pressing the *center key*, which always matched the particular *side key* that had the sample on it. These trials, therefore, cannot be categorized as baseline, but because the stimulus configurations are the same as those on baseline trials, are classified as "old."

The third class consists of the lower two configurations in the center and rightmost sets. These two displays (VHV and HVH) differed from any with which the animals had been trained. They also involved contingencies unlike those of both baseline and old trial configurations; the subject could produce a food pellet by pressing a *side key* that showed the same line as the other *side key* on which the sample appeared, but pressing the center key was always an error. Because these trials differed from the others both in stimulus configuration and in the associated contingencies, they are classified as "new."

For both subjects, accuracy on the conditional line discrimination depended on the trial class. Figure 3 shows Monkey R47's percentage of correct baseline trials (sample on the center key; one side key correct and the other incorrect), old trials (sample on one side key; center key correct, and the other side key incorrect), and new trials (sample on one side key; the other side key correct, and the center

Fig. 2. Configurations of line stimuli after the animal pressed the sample key (S) on moving-sample trials. On trials with side-key samples, the configurations in the upper two rows are classified as "old" and those in the lower two rows as "new."

key incorrect). Data points are for selected sessions that preserve the overall trends. Hue trials were mixed with line trials during Sessions 2 through 13. The accuracies on hue trials remained near 100% and are not shown.

The data point at Session B indicates a

nearly perfect performance in the final baseline session, with all samples appearing on the center key. The next 30 moving-sample sessions only slightly disrupted the animal's baseline-trial performance. During the first moving-sample session, 95% of the new trials

Fig. 3. Monkey R47's performance on conditional line discriminations during the last baseline session (B) and during selected moving-sample sessions. Data points depict the percentage of correct responses for trials with the sample on the center key (baseline trials) and for new and old trials. In Sessions 2 through 13, hue trials were mixed with the line trials.

Fig. 4. Monkey R47's performance during moving-sample Sessions 1 and 3. Bars show the percentage of trials with correct responses for each of the 12 kinds of trials. The stimuli, vertical or horizontal lines on Key 1, Key 2, and Key 3, respectively, are identified under the bars.

were correct, but only 29% of the old trials. The next two sessions brought the old-trial accuracy to 100%, while that of the new trials dropped to 20%. In subsequent sessions, performance in new trials gradually improved to about 80% correct, and old trials dropped to the same level.

The initial difference between old and new trials in Monkey R47's first moving-sample session, and the accuracy reversal that was complete by Session 3, held true for samples on both side keys. Figure 4 shows the accuracy in Sessions 1 and 3 for each of the 12 kinds of trials. In Session 1, baseline trials were highly accurate. On trials with a Key 1 sample, accuracy was 40% on each kind of old trial and about 90% on each new trial. Similarly, with the sample on Key 3, accuracy was very low on the old trials (27% for VHH and only 10% for HVV) and high on the new (100%). On Session 1 trials with a side-key

Fig. 5. Monkey R50's performance on conditional line discriminations during the last baseline session (B) and during sessions with moving sample. Data points depict the percentage of correct baseline, old, and new trials. In Session 1 only, hue trials were mixed with the line trials.

sample, therefore, Monkey R47 selected primarily the other side key and rarely the center key.

By Session 3, along with a perfect performance on baseline trials, the animal's accuracy had become high on old trials (100%) but very low on new (33% and 40% on VHV and HVH trials with Key 1 samples, and 0% and 16% on VHV and HVH trials with Key 3 samples). Like the original pattern in Session 1, the reversal was consistent for samples on both side keys. Now, however, the animal selected primarily the center key and rarely the other side key.

Monkey R50's line discrimination also deteriorated during its first moving-sample session. Unlike Monkey R47, Monkey R50 continued to show a major disruption in the old trials. Figure 5 shows Monkey R50's accuracies during its final baseline session (B) and all eight moving-sample sessions. With samples on the center key, accuracy dropped to 75% but then gradually increased to more than 90% (except in the final session). The animal's new-trial accuracy was 75% at first and then varied between 82% and 94%. Its old-trial accuracy was, like the other animal's, low

at first (48%), and then improved to about 70%.

Figure 6 presents accuracies for the 12 kinds of trials during Sessions 1 and 3, as for Monkey R47. In Session 1, the moving sample caused control by the Key 2 sample to deteriorate; a Key 3 preference was especially pronounced on baseline trials that displayed two vertical stimuli. By Session 3, this preference had disappeared and conditional control had improved. When the sample appeared on Key 1, the accuracy pattern in Session 1 closely resembled that of Monkey R47 (Figure 4)—high (100%) on new trials and low (55%) on old. With Key 1 samples, therefore, the animal was more likely to select the other side key than the center key. This pattern became even more pronounced in Session 3.

With Key 3 samples, however, Monkey R50 did not follow the pattern of selecting the other side key. Instead, it strongly preferred the vertical-line comparison on old trials and showed no obvious pattern on new trials. The animal's responses in Session 3 showed little change except for an overall improvement in accuracy. Monkey R47's initial sharp preference for the other side key on trials with a side-key sample was, therefore, not a necessary outcome of the moving-sample procedure; the other animal showed a similar preference only for trials with a Key 1 sample. Monkey R50's side-key preference was thus conditional on the Key 1 sample, with Key 3 samples controlling instead a mixed pattern, its most pronounced feature being a strong preference for the vertical comparison on old trials.

DISCUSSION

The change from a fixed sample location to a spatially varying sample generated two patterns of conditional discrimination. With hues as stimuli, the monkeys' conditional discriminations remained intact. With lines as stimuli, however, the moving-sample procedure disrupted the conditional discriminations. The subjects no longer matched the lines accurately when the sample and comparisons appeared in novel positions—sample on a side key previously occupied only by comparison stimuli, and a comparison on the center key where only samples had appeared before.

Fig. 6. Monkey R50's performance during moving-sample Sessions 1 and 3. Bars show the percentage of trials with correct responses for each of the 12 kinds of trials. The stimuli, vertical or horizontal lines on Key 1, Key 2, and Key 3, respectively, are identified under the bars.

Considerable exposure of the subjects to the moving sample was required to reestablish even a marginally accurate line discrimination.

On trials with lines as sample and comparison stimuli, other stimuli took control of the animals' behavior. When the monkeys first encountered the moving-sample procedure, they tended to do what they had been taught in baseline. For example, after having pressed a vertical sample on side Key 1, and being faced then with the old configuration VVH, they would continue to press the vertical line on the side key (the previous location of the matching comparison stimulus). Because this was now the sample key, however, continuing to press it after the appearance of comparison stimuli accomplished nothing. The animals then pressed the other side key, even though a nonmatching stimulus was displayed there. After all, pressing a side key had produced

food during baseline training, but pressing the center key had not. (Redundant sample presses were frequently observed in early moving-sample trials, but our recording technique did not permit a quantitative analysis.) Occasional reinforcements of pressing the center key quickly switched Monkey R47's preference from the side keys to the center key, but Monkey R50 retained a side-key preference on trials when the sample was located on Key 1.

With Key 1 and Key 3 samples, side-key preferences automatically guaranteed high accuracies on new trials (VHV and HVH) and low accuracies on old (VVH, HHV, VHH, and HVV). Just as automatically, a change in preference from side to center key reversed the accuracy pattern for new and old trials. Despite the deceptive accuracy levels, therefore, one can conclude that the conditional line discriminations transferred neither to old nor to new trials after the change to moving sample; the selective high accuracies were artifacts. Monkey R47's change in key preference and the gradual course of both animals' subsequent improvement indicate that they had to learn the conditional discrimination anew for trials with side-key samples.

The control that the location of sample and comparison lines had exerted in baseline, therefore, disrupted the conditional line discrimination when the moving-sample procedure was instituted, revealing that the conditional line discrimination was itself conditional upon the spatial positions of the stimuli. The controlling stimuli for the line discrimination were not just horizontal and vertical lines, but horizontal and vertical lines on particular keys; an accurate definition of the controlling stimuli should have specified these locations.

What made the line orientations, but not the hues, susceptible to joint control by sample and comparison location has yet to be determined. The need to specify location as part of the stimulus definition will undoubtedly be circumscribed by variables in the subject's stimulus-control history and sensory equipment, in the currently prevailing contingencies, and in physical details of the experimental arrangements. Such variables will also determine which stimulus features assume control once the sample and comparisons have lost their functions (e.g., Serge, 1985).

When the definition of a stimulus does require that its location be specified, however, a failure to do so may generate unwarranted conclusions about a subject's performance or abilities. For example, a pigeon's failure to generalize a seeming identity-matching performance from one set of hues to another (e.g., Cumming & Berryman, 1965) or from hues to forms (e.g., Farthing & Opuda, 1974) may reflect only the experimenter's failure to recognize that the original controlling stimuli were not just hues, but hues in particular locations. If that is true, an original relation of identity between sample and comparison stimuli would never have existed for the subject and, therefore, could not possibly have transferred to another set of stimuli.

Also, a monkey's failure to demonstrate symmetry in a conditional relation between line samples and hue comparisons (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982) may reflect the experimenter's failure to include key location in the definition of line samples. If so, then for the monkeys, line samples on the center key (with hues on the side keys) would not be the same stimuli when they appeared during testing as comparison lines on side keys (with a hue in the center). A test for interchangeability of sample and comparison functions would be invalid if the stimuli did not maintain their identity when moved from one key to another.

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