MATCHING-TO-SAMPLE PERFORMANCE IN RATS: A CASE OF MISTAKEN IDENTITY?

IVER H. IVERSEN

UNIVERSITY OF NORTH FLORIDA

Three rats had previously acquired a simultaneous matching-to-sample performance with steady and blinking lights. In training, the sample stimulus had always appeared on the middle of three horizontally arranged keys with the comparison stimuli on the side keys. In Experiment 1, the sample stimulus appeared on any of the three keys with the comparison stimuli on the remaining two. The matching-to-sample performance broke down with variable sample and comparison locations; the sample stimulus did not control responding to the comparison stimuli when it appeared on a side key, but it retained control when it appeared on the middle key (as in training). In Experiment 2, the rats were trained with the sample always on the left key. When the sample appeared on either of the trained locations (left or middle key), it retained control for both locations. When the sample then appeared on any of the three keys, as in Experiment 1, sample control did not transfer to the untrained location (right key). The experiments demonstrate that training with fixed sample and comparison locations may establish spatial location as an additional controlling aspect of the stimuli displayed on the keys; stimulus location had become part of the definition of the controlling stimuli. The rats' performance seemed best described as specific discriminations involving the visual stimuli and their spatial locations rather than as identity matching.

Key words: identity matching, sample location, reflexivity, symmetry, mistaken identity, nose key, rats

A common conditional discrimination is that established with the matching-to-sample procedure in which stimulus–response–reinforcer relations are placed under the control of other stimuli (Mackay, 1991). For example, Stimulus A (say a red light) may appear on the center of three horizontally arranged keys. After a response to this key, Stimulus A appears on one outer key and Stimulus B (say a green light) appears on the other outer key. The procedure is a conditional discrimination because the first stimulus, the sample, determines which of the two comparison stimuli is correct for a selection. When one of the comparison stimuli is the same as, or identical to, the sample stimulus, the task often is called an *identity matching procedure.* Correspondingly, when a subject's choice of the correct comparison stimulus is under adequate control of the physically identical sample stimulus, the performance is commonly called *identity matching*—the subject is said to be matching to sample.

If a subject can also perform adequately when novel stimuli replace the training stimuli, the performance is often called *generalized identity matching* or *true matching,* or is taken

as evidence that training generated an identity concept (for a review see Mackay, 1991; for examples see Herman, Hovancik, Gory, & Bradshaw, 1989; Kastak & Schusterman, 1994; Oden, Thompson, & Premack, 1988; Overman & Doty, 1980; Wright, Cook, Rivera, Sands, & Delius, 1988; Zentall, Edwards, Moore, & Hogan, 1981; for a critical examination of the identity matching issue see Dube, McIlvane, & Green, 1992).

Even before asking whether a subject can match untrained stimuli, one may ask the apparently simpler question whether the subject can still match the familiar training stimuli when they are presented in novel locations. That is, does Stimulus A as a sample control a response to Stimulus A as a comparison when one or both appear in a different location? If the conditional discrimination breaks down when the stimuli are relocated, then the spatial locations of sample and comparison stimuli are evidently taking part in the controlling aspects of the stimuli.

This issue was examined in a previous experiment with 2 rhesus monkeys (Iversen, Sidman, & Carrigan, 1986). First, the sample stimulus was always presented on the center key, and the comparison stimuli were presented on the two outer keys; both subjects acquired highly accurate performance with

Correspondence should be addressed to Iver Iversen, Department of Psychology, University of North Florida, Jacksonville, Florida 32224 (E-mail: iiversen@gw.unf.edu).

both hue-hue (red vs. green) and line-line (horizontal vs. vertical) stimuli. Next, the sample stimulus appeared on any key and the comparison stimuli appeared on the remaining keys. Hue stimuli controlled the monkeys' performance irrespective of their location, whereas line stimuli lost control over performance with variable locations of sample and comparison stimuli. The results demonstrated that the controlling stimuli in the conditional line-line discrimination were not only the lines but also the particular spatial locations they had occupied during training.

The purpose of the present experiment was to determine whether this finding could be replicated using subjects of another species. In a previous experiment, rats had acquired high accuracy in a conditional discrimination with steady versus blinking lights that appeared on three horizontally arranged nose keys (Iversen, 1993). In that experiment, the sample always appeared on the middle key and the comparison stimuli appeared on the outer keys. Using the same subjects in the present experiments, the stimulus locations were varied so that the sample could appear on any of the three keys. If the sample did not control selections when in a new location, then one could question the appropriateness of describing the rat's highly accurate performance as "identity matching" in the customary identity matching procedure with fixed key locations.

EXPERIMENT 1

Experiment 1 followed immediately after the training described by Iversen (1993). Within a session, the sample now appeared with equal probability on any of the three keys, and the comparison stimuli occupied the remaining two keys. The data were analyzed at increasing levels of refinement (e.g., Iversen, 1991) to reveal possible sources of stimulus control that the previous training with fixed spatial locations of sample and comparison stimuli might have generated.

METHOD

Subjects

Three female Long Evans hooded rats, 6 to 7 months old at the start of the experiment, were maintained at 85% of their free-feeding body weights. The rats were housed individ-

ually with free access to water and were fed approximately 1 hr after each daily session.

Apparatus

One chamber (30 cm wide, 25 cm deep, and 25 cm high) made of clear and opaque Plexiglas was located in a sound-attenuating cubicle with white masking noise and a fan. One opaque wall had a row of three nose keys (2 cm diameter), 15 cm above the grid floor. The middle key was centered on the wall, and each side key was 9 cm from the middle key. Each key required a force of approximately 0.1 N for operation. A Gerbrands G5120 dispenser delivered standard Noyes 45-mg food pellets into a recessed opening (3 cm deep) covered by a hinged flap (5 cm by 6 cm), 1 cm above the floor and centered below the middle key. A 0.5-s beeping sound from a Sonalert® (28 VDC with a 20K ohm resistor in series) accompanied each pellet delivery.

Each key was illuminated from behind by a 14-VDC white light. The stimulus projected on each key was either a steady white light or a white light blinking at 0.1-s intervals. The chamber was dark except for the lights that appeared on the response keys. Programming and recording were accomplished by a Tandy Model 102 computer.

Procedure

Fixed sample location. Before the present experiment, Rats 1, 2, and 3 had received 63, 65, and 54 100-trial sessions of matching-to-sample training with the sample always appearing on the center key (Iversen, 1993). That training had resulted in matching-to-sample performance at 90% correct or higher and is referred to here as baseline training.

Variable sample location. Immediately after baseline training, the sample stimulus appeared on any of the three keys with equal probability. A press on the sample key produced the comparison stimuli on the other two keys while the sample remained. A press on the comparison key that displayed the same stimulus as the sample key produced a food pellet and extinguished the keylights. A press on a nonmatching key extinguished all keylights without food delivery. Figure 1 shows the 12 sample–comparison combinations that were engendered by the three sample locations after the rat pressed the sample key.
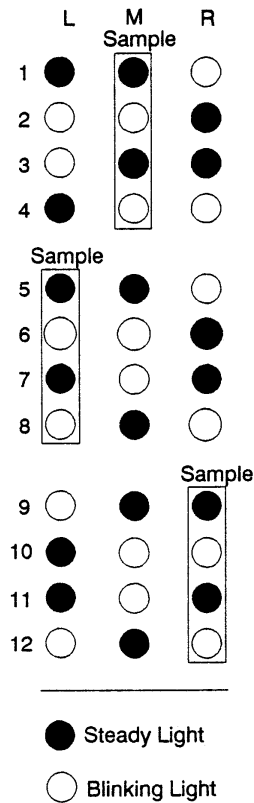
Fig. 1. Schematic of the 12 possible configurations of the two stimuli, steady and blinking lights, as they appeared on the left (L), middle (M), and right (R) keys after the rat had pressed the key that displayed the sample. The top block shows the four stimulus configurations with the sample on the middle key, as in baseline training; the lower two blocks show the stimulus configurations for the sample on each of the two side keys. For all trials, a press on the comparison stimulus that was identical to the sample was reinforced. Sample stimuli are boxed for ease of identification.

Each session had 96 trials, 32 for each sample location, with eight trials of each of the 12 trial types. Eight sessions were scheduled for Rats 1 and 2, but 15 sessions were scheduled for Rat 3 because the performance changes were slower for this rat. The trials were distributed in mixed order with the following restrictions: The sample could not appear on the same key for more than two consecutive trials; the same key could not be correct on more than two consecutive trials; and the same stimulus could not be correct on more than two consecutive trials. The outcome of a trial did not affect the configuration for the next trial (i.e., a correction procedure was not used). Immediately before a daily session, each rat

received a 16-trial warmup session with the sample always appearing on the middle key, as in baseline training. Each rat completed nearly all of these sessions without any incorrect responses. The intertrial interval was 3 s.

RESULTS

The percentage of correct responses, pooled for all trials, is shown in Figure 2 for each session with variable sample location; the mean percentage correct for the last five sessions of baseline training is shown at B. With the moving-sample procedure, the overall accuracy immediately dropped from above 90% to slightly above 60% and remained at that level for each rat. Even though the prior baseline training had resulted in a very high accuracy, the rats did not match to sample when the same familiar sample and comparison stimuli appeared in new locations on the same familiar keys.

The data were analyzed in detail to determine possible sources of control of the performances. Accuracy was analyzed separately for different stimulus configurations and for each sample location; performance changes were tracked trial by trial; and latencies to respond to sample and comparison stimuli were analyzed along with redundant presses to the sample key.

Control by Sample Location

Figure 3 shows the percentage of correct responses separately for each sample location. Accuracy remained at the high baseline level for middle-key samples for Rats 1 and 2 and dropped to near 80% for Rat 3. (Because middle-key-sample control deteriorated for Rat 3, six 100-trial sessions with only the middle-key sample were conducted between Sessions 9 and 10. Accuracy improved to above 90% during this intervening return to baseline.) Thus, middle-key samples retained control over which comparison stimulus the rat pressed. But side-key samples did not; the accuracy immediately dropped to and remained at or near 50% for all 3 rats. The conditional sample control with the sample on the middle key was retained but evidently did not transfer to the same stimuli on the same familiar keys when the sample appeared on a side key. This analysis shows that the consistent above-chance (near 60%) performance with variable sample location (Figure
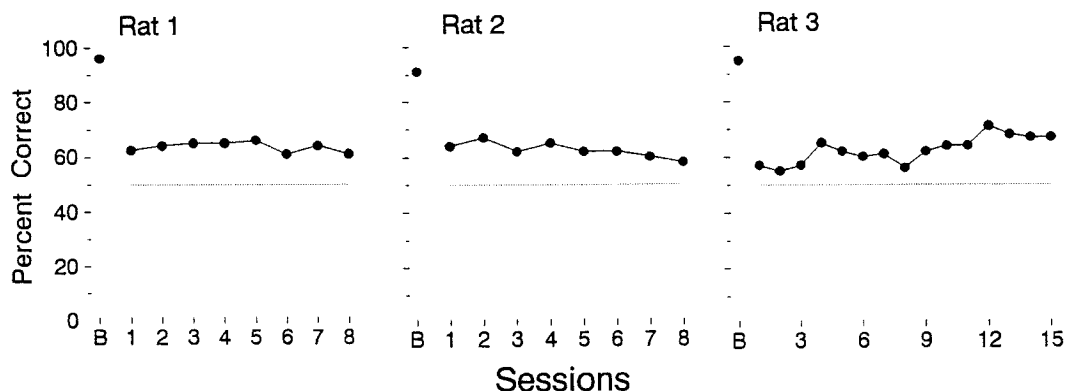
Fig. 2.   Overall percentage of correct responses for each session when the sample location varied among three keys. Also shown is the percentage of correct responses averaged for the last five sessions of baseline training (B), in which the sample always appeared on the middle key. For Rat 1, Session 1 had only 80 trials; this session was terminated prematurely because of excessive pausing (see also Figure 6). For Rat 3, six sessions with the sample always on the middle key were scheduled between Sessions 9 and 10.

2) was a composite of high accuracy for the middle-key sample and near-chance performance for both side-key samples.

Stimulus Configurations and Key Positions

In the previous experiment with monkeys (Iversen et al., 1986), we analyzed the data conditional on the stimulus configuration that the subject faced after having pressed the sample key. For trials with a side-key sample, the stimulus configuration either resembled the familiar ("old") configurations on baseline trials (i.e., SSB, BBS, BSS, and SBB; Configurations 5, 6, 9, and 10 in Figure 1) or pre-

sented a novel ("new") configuration (i.e., BSB or SBS; Configurations 7, 8, 11, and 12 in Figure 1). Figure 4 presents the accuracy for old and new configurations for side-key-sample trials for each session. All 3 rats began at near 50% for both old and new configurations. Over sessions, Rats 1 and 3 developed a consistently high (near 100%) accuracy for trials showing the old display and a low (near 0%) accuracy for the new display. Rat 2's performance remained at near 50% for both display types. Do these data indicate that Rats 1 and 3 in fact matched correctly on trials with the familiar configurations? Because the mid-
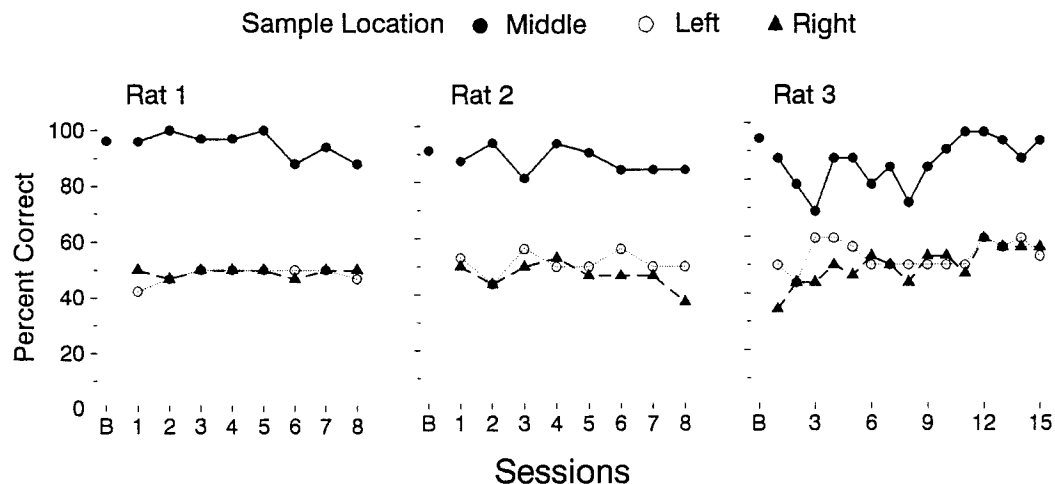

Fig. 3.   Percentage of correct responses for each sample location for each session when the sample location varied among three keys. Also shown is the percentage of correct responses averaged for the last five sessions of baseline training (B), in which the sample always appeared on the middle key.
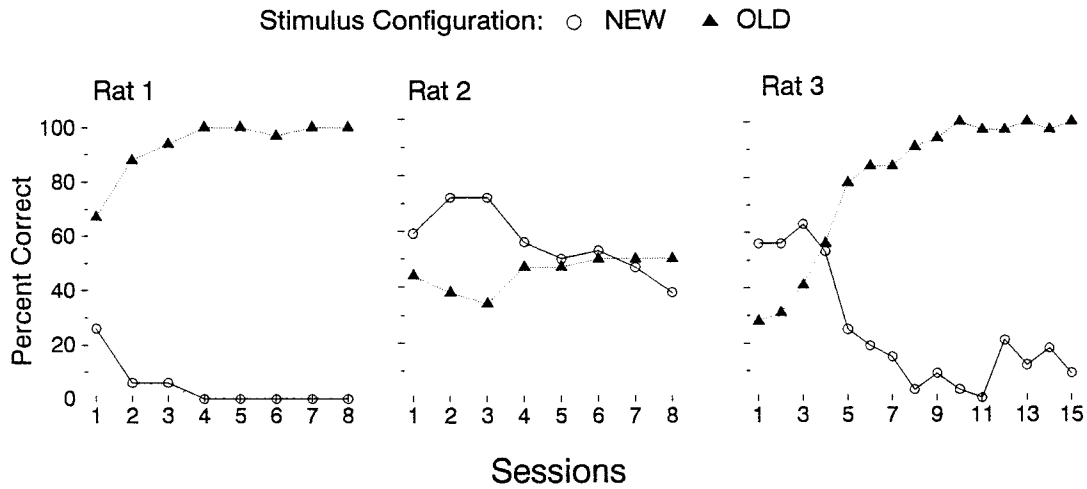
Stimulus Configuration: ○ NEW ▲ OLD

Fig. 4. Percentage of correct responses for two configurations of sample and comparison stimuli after the sample key has been pressed when the sample location varied among three keys. Data are shown for each session for side-key-sample trials only. (Accuracy data for middle-key-sample trials appear in Figure 3.) "Old" refers to configurations that resemble the baseline trials (i.e., SSB, BBS, BSS, and SBB; S for steady light and B for blinking light), and "new" refers to configurations that are novel (i.e., SBS and BSB).

dle key always displayed the correct comparison for old configurations and the incorrect comparison for new configurations (see Figure 1), the respective high and low accuracy scores suggest that Rats 1 and 3 must have pressed the middle key for most trials with a side-key sample.

To examine the possibility that key locations rather than the stimuli controlled responding, Figure 5 shows the percentage of trials with a press on the middle key after the sample had appeared on the left or right side

key. By Session 4, Rat 1 simply pressed the middle key on all trials with a side-key sample. The same pattern, albeit somewhat more variable, emerged for Rat 3 after five sessions. A different and more complex pattern developed for Rat 2. By Session 4, Rat 2 pressed primarily the middle key on trials with the left-key sample. But on right-key-sample trials, Rat 2 almost exclusively pressed the other side key from Session 2 on. Thus, for side-key samples, the sample *location* but not the sample *stimulus* controlled Rat 2's performance.
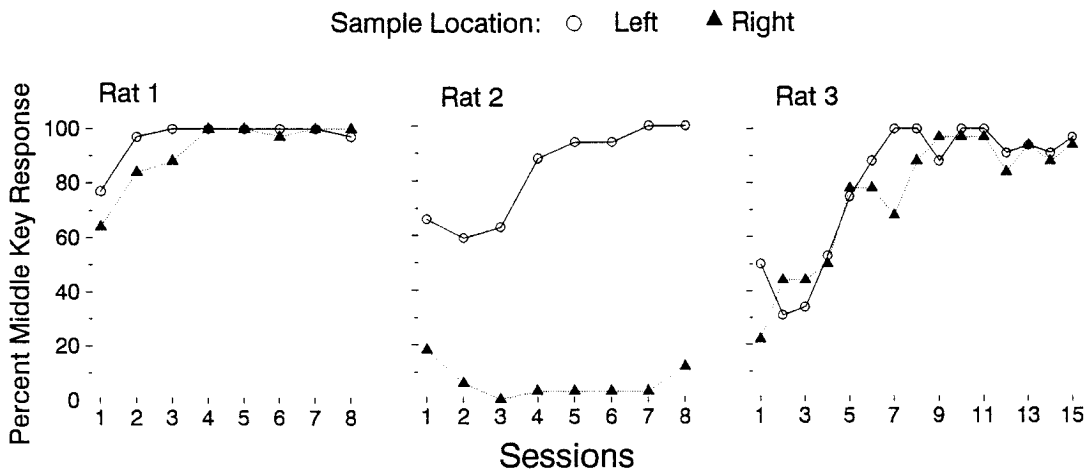
Sample Location: ○ Left ▲ Right

Fig. 5. Percentage of trials with a response to the middle key for each side-key-sample location for each session when the sample location varied among three keys.

For left-key samples, Rat 2 pressed the middle key, and for right-key samples, Rat 2 pressed the left side key. In contrast, for middle-key samples, the sample *stimulus* controlled which side key the rat pressed (Figure 3). For each rat, the near-chance performance for side-key samples shown in Figure 3 did not reveal these sources of strong control by key location. The data indicate that key location and not stimulus configuration controlled the rats' performance on side-key-sample trials. The high accuracy for old configurations was therefore illusory, as was the low accuracy for the new configurations (i.e., Figure 4).

Trial-by-Trial Analysis

To allow an in-depth examination of how the performance patterns developed, Figure 6 displays the outcome of all individual trials for each rat. (For Rat 1, the first session was terminated prematurely after 80 trials because of excessive pausing. For convenience of exposition, only odd-numbered sessions are shown for Rat 3.) For Rat 1, high accuracy on trials with the middle-key sample is evident by the predominance of filled squares in the top clusters across sessions. For both side-key samples, Rat 1 in Session 1 pressed the comparison key with the steady light on 44 of the 54 trials (81% preference for steady light). However, in Session 2, the preference for the comparison with the steady light subsided, in that Rat 1 pressed the middle key on 91% (58 of 64) of the side-key-sample trials, a pattern that became nearly permanent from Session 3 on. For Rat 3, incorrect presses occurred sporadically with the sample on the middle key. For side-key samples, the response pattern changed gradually over the first eight sessions and thereafter closely resembled that for Rat 1. For Rat 2, high accuracy was maintained on middle-key-sample trials. When the sample appeared on the right side key, Rat 2 almost always pressed the other side key; this pattern was evident from Session 1. For trials with the left-key sample, responding varied for the first three sessions but then settled in the same pattern as for Rats 1 and 2.

Trial-by-trial analyses showing the outcome of several thousand individual trials are uncommon in conditional discrimination procedures (i.e., Figure 6 presents data for a total of 2,288 trials). However, these analyses offer a source of information that can be used to answer future unexpected questions that cannot be answered by examining only the averaged data. Hence, a trial-by-trial display, such as that presented in Figure 6, has an archival value in addition to revealing performance patterns that are independent of the experimenter's sampling method.

Initial Reactions to Side-Key Samples

On the first side-key-sample trials in Session 1, the rats initially pressed the sample repeatedly after the comparison stimuli were lit, and then pressed a comparison key. The highest number of extra sample-key presses on one trial was 8, 31, and 9 for Rats 1, 2, and 3, respectively. The repeated sample-key presses accomplished nothing and were slowly extinguished over the course of Sessions 1 and 2.

Responding to the comparison stimuli might conceivably have been controlled by the sample stimulus on the first few trials with variable sample location. To illustrate the initial reaction of the rats, Table 1 shows the performance on individual trials with a side-key sample for the first half of Session 1. Rat 1 pressed the middle key on the first six side-key-sample trials. Thereafter, Rat 1 pressed the middle key on the majority of the trials. For Rat 2, no particular pattern was evident for the first 10 side-key-sample trials. Thereafter, Rat 2 pressed the left side key or the middle key. Rat 3 predominantly pressed the other side key for the first 15 trials and then pressed mainly the middle key thereafter. Thus, there was no evidence of stimulus control for side-key samples from the very beginning of the moving-sample procedure for any rat. In contrast, control by the middle-key sample was not disturbed by the side-key-sample trials; on middle-key-sample trials, Rats 1, 2, and 3 made one, zero, and two incorrect presses, respectively, during the first half of Session 1 (to avoid crowding, data from these trials are not shown in Table 1, but see Figure 6).

Latencies

To determine whether the rats could discriminate the sample locations, the mean latencies to respond on the sample key (time from sample onset to the first press on the sample key) were calculated for each sample location for Sessions 1 and 8. The mean latencies for

Rat 1

Rat 2
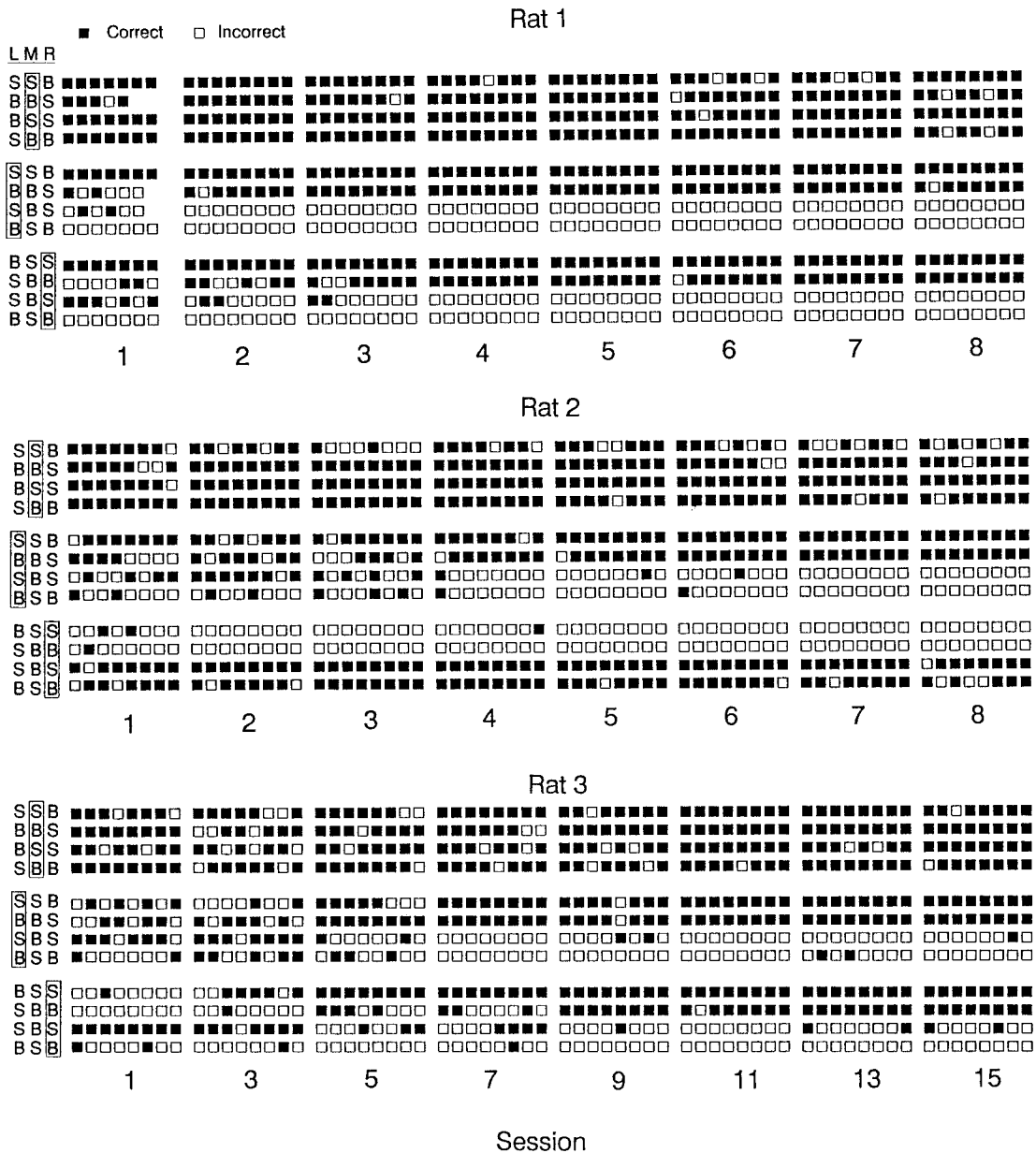
Rat 3

Session

Fig. 6.   Outcome on all individual trials for each session with variable sample location for Rats 1 and 2 and for odd-numbered sessions for Rat 3. Trials are presented successively for each trial type (identified in the left column) and read from left to right. For each rat, the top cluster for a session shows trials with middle-key sample, the middle cluster shows trials with left-key sample, and the bottom cluster shows trials with right-key sample. A filled square indicates that a response occurred to the correct comparison stimulus (i.e., a reinforced response); an open square indicates a nonmatching unreinforced response. Session 1 for Rat 1 was terminated prematurely after 80 trials because of excessive pausing. This figure displays 2,288 individual trials, 768 (96 × 8) each for Rats 2 and 3 and 752 for Rat 1 (768 − 16).

Table 1

Performance on individual trials with a side-key sample for the first half of Session 1 with variable sample location. All rats had the same trial sequence; side-key sample trials were mixed with middle-key sample trials (not shown here). Letters in the left column indicate the sample stimulus (S for steady light and B for blinking light) and its position on the left (L), middle (M), or right (R) key; a + indicates the location of the correct comparison stimulus. Columns labeled *Comparison* show the comparison key each rat pressed (L, left; M, middle; and R, right), and columns labeled *Sample presses* show how many presses occurred on the left or right sample key after it had been pressed once. A + on the comparison key pressed indicates a reinforced trial.

| | Trial type | | | Rat 1 | | | | | Rat 2 | | | | | Rat 3 | | | | |
| | | | | Comparison | | | Sample presses | | Comparison | | | Sample presses | | Comparison | | | Sample presses | |
L	M	R	L	M	R	L	R	L	M	R	L	R	L	M	R	L	R
B		+		M		3				R+	4				R+	9	
	+	S		M+			6	L				19	L				4
S		+		M		3			M		3				R+	0	
B	+			M+		3			M+		4				R	4	
S	+			M+		0				R	5				R	4	
+		B		M			4		M			2	L+				3
	+	B	L				3	L				7	L				2
+		S	L+				7	L+				3	L+				4
B		+		M		0			M		8			M		4	
S		+			R+	8				R+	11				R+	0	
+		B		M			2	L+				4		M			5
B	+				R	0			M+		12				R	2	
	+	S		M+			0	L				0	L				2
+		S	L+				3		M			31	L+				1
	+	B	L				6		M+			1	L				1
S	+			M+		7			M+		3			M+		1	
	+	S		M+			3		M+			0		M+			0
+		S	L+				6	L+				0	L+				3
	+	B	L				4	L				1	L				1
+		B		M			0	L+				0		M			1
B		+		M		3			M		1			M		1	
S	+			M+		5			M+		2				R	1	
B	+			M+		1			M+		9			M+		4	
+		B		M			0	M				1		M			3
	+	B	L				4	L				0	L				2
S		+		M		1			M		1				R+	0	
+		S		M			1	L+				2	L+				1
B	+				R	0			M+		5			M+		3	
S		+			R+	6			M		3			M		0	
	+	S		M+			7	L				3	L				0
B		+		M		0				R+	1			M		1	
S	+			M+		1			M+		2			M+		2	

the last five sessions of baseline training are also shown in Table 2. For Rats 1 and 2, the moving-sample procedure immediately lengthened all sample latencies compared to baseline training and most so for side-key samples. For Rat 1, several pauses of up to 5 min began to occur in Session 1. For Rat 3, latencies were only slightly higher for side-key samples in Session 1. For all rats, latencies for the middle-key sample had returned to their baseline values by Session 8, whereas latencies were consistently and considerably longer for side-key samples. (For Rat 3, sample latencies after Session 8 were similar to those obtained by Session 8.) Thus, the rats could discriminate middle- versus side-sample locations because side-key samples generated longer latencies than did middle-key samples. Therefore, failure of the sample to control responding to the comparison stimuli did not result from a failure to detect that the sample appeared on a side key.

Mean latencies to respond to the compar-

Table 2

Latencies to the sample stimulus (seconds) for each sample key location. Data are averages for the last five sessions of baseline training with a fixed sample location (always on the middle key) and for Sessions 1 and 8 with variable sample location.

| | | Sample location | | |
| | | Fixed | Variable | |
Rat	Sample key	Baseline	Session 1	Session 8
1	Left		28.9	16.6
	Middle	2.3	10.1	2.1
	Right		16.8	10.7
2	Left		5.5	6.7
	Middle	2.8	3.9	3.1
	Right		9.5	12.4
3	Left		3.2	6.2
	Middle	2.4	2.8	2.8
	Right		3.3	6.2

ison stimuli (time from presentation of the comparison stimuli to a press on either key that displayed a comparison stimulus) were also analyzed for each sample location for Sessions 1 and 8 in Table 3. In addition, Table 3 shows the mean number of repeated presses on the sample key after the first press on the sample key illuminated the comparison keys. The mean comparison latencies and mean number of repeated sample-key presses for the last five sessions of baseline training are also shown in Table 3. For Session 1 with variable sample location, latencies to the comparison stimuli increased after a side-key

sample but remained nearly the same as in baseline training for middle-key samples. In addition, for all rats, the number of redundant presses on the sample key increased for side-key samples but not for middle-key samples. By Session 8, latencies to the comparison stimuli had become similar for all sample locations and were now the same as those obtained in baseline training. Similarly, the number of repeated presses on the sample key had dropped to near zero. The data suggest that the longer latencies to the comparison stimuli in Session 1 resulted from the repeated presses on the sample key. When these presses had virtually disappeared, the latencies to the comparison stimuli became similar to those obtained in baseline training.

DISCUSSION

The sample control of responding to the comparison stimuli, which had been established in baseline training with fixed location of sample and comparison stimuli, did not transfer to new sample locations. The results show that the performance cannot be described as matching sample and comparison stimuli based only on their physical identity. Sample control disappeared when the same two stimuli (steady and blinking lights) appeared in different locations on the same three keys. Baseline training with fixed stimulus location evidently had not established an identity relation but instead had made each

Table 3

Latencies to the comparison stimuli (seconds) and repeated presses on the sample key (number per trial) after the comparison stimuli had appeared. Data presented are averages for the last five sessions of baseline training with fixed sample location (always on the middle key) and for each sample location for Sessions 1 and 8 with variable sample location.

		Sample location					
		Fixed		Variable			
		Baseline		Session 1		Session 8	
Rat	Sample key	Latency	Sample presses	Latency	Sample presses	Latency	Sample presses
1	Left			2.5	2.1	0.7	0.3
	Middle	0.7	0.02	0.9	0.5	0.7	0.2
	Right			2.9	2.7	0.7	0.4
2	Left			3.7	3.3	0.8	0.3
	Middle	0.9	0.1	1.2	0.4	0.9	0.1
	Right			2.9	3.4	0.9	0.2
3	Left			2.8	1.5	1.1	0.08
	Middle	1.0	0.06	1.6	0.3	1.0	0.04
	Right			2.5	1.4	1.2	0.07

stimulus control both by its physical properties *and* by its spatial location. The results of Experiment 1 replicate the findings from the previous experiment with 2 monkeys (Iversen et al., 1986). In that experiment, matching-to-sample performance with line-line stimuli broke down with variable sample and comparison locations. As in the present experiment, the middle-key sample retained control, and the accuracy dropped to near 50% for side-key samples.

Increasing levels of resolution in data analysis revealed that the performances were not random, even though the accuracy scores were near 50% for side-key samples. Thus, Rats 1 and 3 developed consistent pressing on the middle key on nearly all side-key-sample trials. Rat 2 also came to press the middle key on left-key-sample trials but pressed the other side key on right-key-sample trials. These response patterns resulted in the near 50% accuracy. Instead of being random, the performance may be controlled by stimuli other than those displayed on the response keys. On side-key-sample trials, responding was controlled by key location, not by the visual stimuli on the keys.

The present experiment revealed additional orderly changes in latencies to respond to the sample and comparison stimuli. The latency increased for side-key samples for all rats, indicating that the rats could at least discriminate side-key samples from middle-key samples (before the comparison stimuli were turned on). Because the accuracy was very high for the middle-key sample and about 50% for side-key samples, the rate of obtained reinforcement became different for middle- and side-key samples. The consistently longer latencies to side-key samples obtained by Session 8 were presumably controlled by this relatively lower probability of obtained reinforcement on side-key-sample trials.

An analysis at the even finer level of individual trials revealed evidence of control that was not available at the coarser levels. Thus, on trials with side-key samples, the initial reaction of the rats after they had pressed the sample key was to press the same key repeatedly before they pressed one of the comparison keys. This performance shows that baseline training had established strong control by the side-key location of the comparison

stimuli. The initial reaction of the rats was to do what they had done in baseline training. They pressed a side key after they had pressed the sample key. Given that the sample now occupied a side-key location, the resulting behavior was repeated presses on the side key that presented the sample stimulus. In other words, the rats were pressing the side key (that showed the sample) as if that key displayed the correct comparison stimulus. The monkeys in Iversen et al. (1986) similarly pressed the sample key repeatedly on the first few trials of the moving-sample procedure. One monkey also developed a consistent preference for the middle-key comparison for both side-key samples, as did Rats 1 and 3 in the present experiment. The performance of the other monkey resembled that of Rat 2 in developing a mixed pattern of a preference for the other side key for left-key-sample trials and a stimulus preference for right-key-sample trials.

An obvious question for further analysis is to determine why the moving-sample procedure is so likely to generate almost exclusive pressing on the middle key on side-key-sample trials for some subjects. Possible sources of control may be separated into those generated by past response–reinforcer contingencies (in baseline training) and those generated by prevailing response–reinforcer contingencies (with variable sample location). If performance were controlled by past contingencies, then evidence of such control should be apparent right after introduction of the moving-sample procedure. On the other hand, control by prevailing contingencies might take some time to develop. Two sources of control generated by past contingencies may be considered here. In baseline training, a reinforced response was always on a side key, never on the middle key. Apparently, control by prior location of a reinforced response was not very strong in the new situation, because only Rat 3 was likely to press the other side key after having pressed a side-key sample on the first few trials in Session 1 (Table 1). Another aspect of baseline training was that a reinforced response always required a switch one key over (i.e., from a press on the middle key to a press on one of the side keys). However, there was no evidence of this one-key-over pattern in Session 1. Only Rat 1 consistently pressed the middle key on side-key-sample trials on the

first few trials of Session 1 (Table 1). Because a one-key-over pattern did develop over sessions, a possible source of control may be sought in prevailing rather than past response–reinforcer contingencies.

When all 12 trial types are considered together (see Figure 1), the probability of reinforcement is the same on each key. However, when trials with side-key samples are considered together, the probability of reinforcement is twice as high on the middle key as on either side key alone. That is, on each side-key-sample trial, the middle key always displays one of the comparison stimuli while the other comparison stimulus appears on the opposite side key. On each side-key-sample trial, the probability of reinforcement is, of course, the same on the middle key (.5) as on the other side key (.5). Nonetheless, combining all trials with a side-key sample, a response to the middle key is reinforced twice as often as a response to each of the side keys because the middle key displays a comparison stimulus on *each* side-key-sample trial. Because the latency data showed that the rats discriminated the sample location, it is meaningful to separate the probabilities of reinforcement in this manner. Thus, the relatively higher probability of obtaining a reinforcer by pressing the middle key on side-key-sample trials may be a possible explanation of the gradual development of consistent pressing on the middle key on most side-key-sample trials. Kamil and Sacks (1972) and Fersen, Emmerton, and Delius (1992) also reported that an asymmetrical distribution of reinforcement opportunities may generate consistent key preferences in conditional discrimination procedures.

EXPERIMENT 2

Experiment 2 attempted to establish accurate matching-to-sample performance with the moving-sample procedure by training each sample location separately. All rats were trained with the sample always on the left side key until accuracy reached a high level. The moving-sample procedure was then reintroduced. Rat 3 was also trained with the sample always on the right side key. This training was followed by one more session of the moving-sample procedure.

METHOD

Subjects and Apparatus

The rats from Experiment 1 participated in Experiment 2. After completion of Experiment 1, 7 to 12 sessions with the sample always on the middle key were scheduled before Experiment 2 began. The apparatus was the same as for Experiment 1.

Procedure

The sample appeared on only the left side key for 65, 47, and 21 sessions for Rats 1, 2, and 3, respectively. Then, from session to session, the sample appeared either on the left key or the middle key throughout a session for 15, 22, and 13 sessions for Rats 1, 2, and 3, respectively. Thereafter, the moving-sample procedure was reintroduced in two steps. First, the sample stimulus appeared on the left or the middle key in mixed order within one session (i.e., a moving-sample procedure restricted to the two trained sample locations, middle and left keys). Next, for two sessions the sample stimulus appeared on any of the three keys exactly as it had in Experiment 1. Training sessions consisted of 100 trials; sessions with two variable sample locations contained 64 trials, and sessions with all three sample locations contained 96 trials. Some exceptions to this general procedure for Rats 1 and 2 are indicated in the results.

Because left-key-sample control was difficult to obtain for Rats 1 and 2 even after extended training, only Rat 3 received training (25 sessions) with the sample always on the right side key. Then followed 10 sessions with the sample always at the same location within a session, but that location varied among the three keys from session to session. Last, Rat 3 had one session with variable sample location using all three keys.

RESULTS

Figure 7 shows the percentage of correct responses with the sample always on the left side key for the first 25 sessions for Rats 1 and 2 and all 21 sessions for Rat 3. Also shown is the percentage of trials with a response to the comparison stimulus that appeared on the middle key. Matching-to-sample performance with the left-key sample was difficult to establish for Rats 1 and 2. After they had pressed the left-key sample, both rats then pressed the
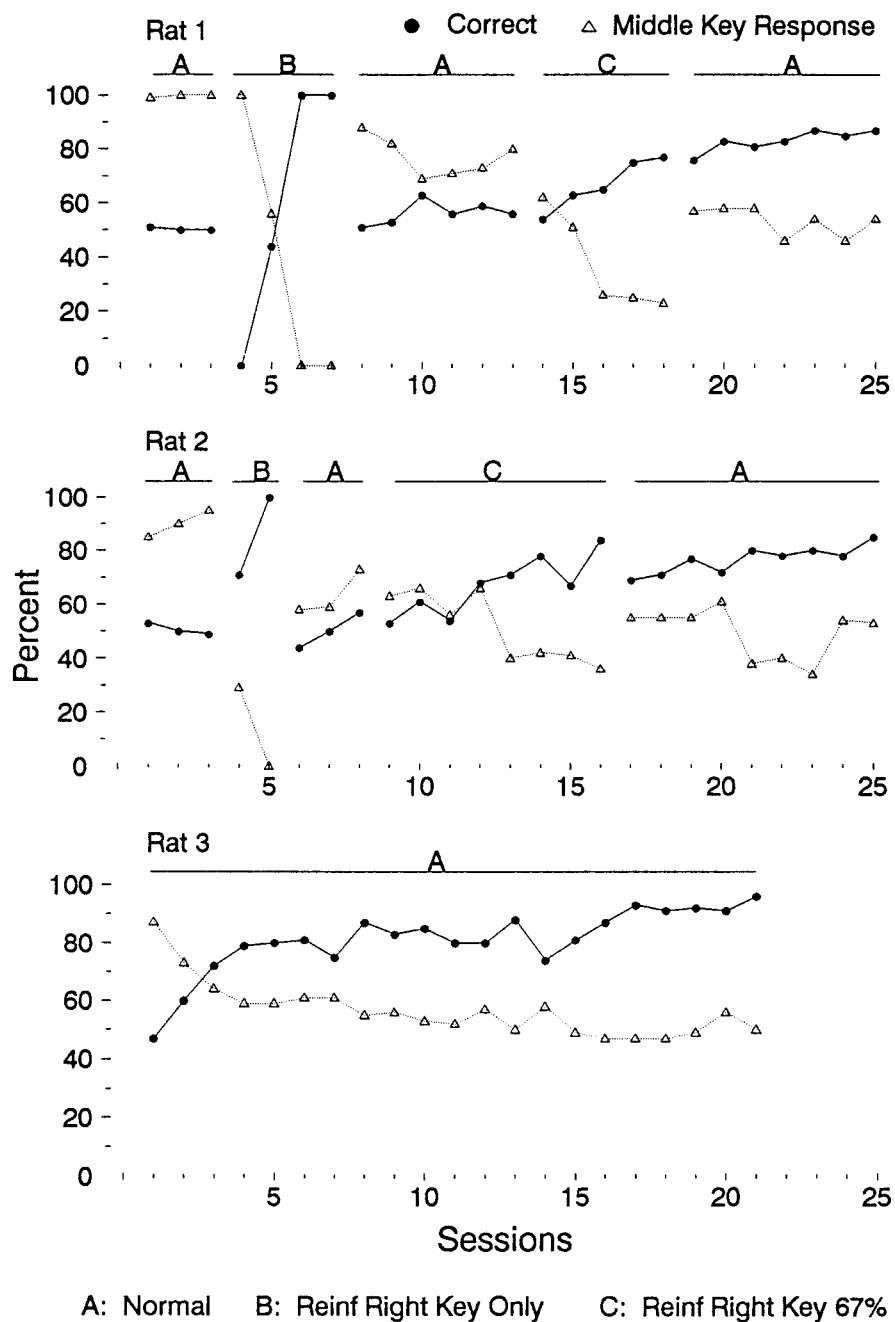
Fig. 7.   Percentage of correct responses with the sample stimulus always appearing on the left side key and the percentage of trials with a response to the comparison stimulus on the middle key in Experiment 2. A, B, and C indicate the training procedures. A: The correct comparison appeared equally often on the middle key and the right side key. B: The correct comparison stimulus appeared on the right side key on all trials. C: The correct comparison stimulus appeared on the right side key on 67% of the trials.

middle key on nearly all trials in the first three sessions; accuracy therefore was at or near 50%. To avoid intermittent reinforcement of presses on the middle key and to generate presses on the right side key, the general procedure was altered so that the correct comparison stimulus appeared only on the right side key (i.e., sessions contained only Trial Types 7 and 8 shown in Figure 1); four and two sessions were scheduled for Rats 1 and 2, respectively (see B in Figure 7).

Remarkably, Rat 1 completed the first session (Session 4) with the correct comparison always on the right side key without a single reinforcement by pressing the nonreinforced middle key on all trials. Only by Session 6 had responding shifted to the right side key as intended by the procedure. For Rat 2, responding to the middle key occurred exclusively for the first 25 trials of Session 4, and by Session 5 responding occurred exclusively on the right side key. These data testify to the strong and rigid control exerted by key location.

The correct comparison then again appeared equally often on the middle and right keys for six and three sessions for Rats 1 and 2, respectively. However, frequent responding to the middle key returned for both rats, and the accuracy was near 50%. The trial distribution was therefore altered again. The proportion of trials with the correct comparison stimulus displayed on the right side key was increased to .67; this procedure was in effect for five and eight sessions for Rats 1 and 2, respectively (C in Figure 7). This procedural change generated an intended preference for the right side key, as seen in the decreased percentage of responses to the middle key. The original trial distribution (A in Figure 7) was reinstated by Sessions 19 and 17 for Rats 1 and 2, respectively. The percentage correct further increased for both rats. The middle key no longer exerted control over responding, as seen in the near 50% choice of the middle key. However, the performances were quite variable after Session 25, and several more sessions (40 for Rat 1 and 22 for Rat 2) were required before the accuracy was consistently above 80%. Rat 3 also pressed the middle key on most trials on Session 1 with the left-key sample. In contrast to the data for Rats 1 and 2, the data for Rat 3 showed that the sample stimulus quickly came to control responding to the comparison stimuli, with

accuracy consistently reaching 80% or higher by Session 17.

After accuracy had been at least 80% for five sessions with the left-key sample, sessions with the middle-key sample alternated with left-key-sample sessions. Accuracy on sessions with the middle-key sample was initially near 75% (compared to sessions before training with the left-key sample, on which accuracy was 90% or higher). However, after one or two sessions with the middle-key sample, accuracies reached 90% or higher for all rats, as it had in Experiment 1.

The left side of Table 4 shows the percentage of correct responses to each sample location when the left and middle sample locations varied within two sessions (Tests 1 and 2). Data in parentheses give accuracy when the sample location was fixed throughout the session before the restricted moving-sample procedure was implemented (data are averaged for the last two sessions of the same kind). When the sample location varied within two test sessions, control was retained for the middle-key sample but deteriorated somewhat for the left-key sample for Rats 1 and 2. For Rat 3, control was retained for both sample locations with an accuracy comparable to sessions with a fixed sample location.

After six to eight more sessions with the left or middle key alternating as a fixed sample location, the sample varied among all three key locations (as in Experiment 1) for one session (Test 3). For all rats, the middle-key sample retained control but the side-key samples did not. Only the left-key sample showed meager evidence of control for Rat 3 (with 78% accuracy). For the untrained right-key sample, accuracy was at or near 50% for all rats. The results demonstrate that the additional training with the sample on the left key was not sufficient to generate sample control for all three key locations. Also, the sample control that had been established when the sample always appeared on the left key could not be maintained when untrained right-key-sample trials were mixed with left- and middle-key-sample trials. For Rats 1 and 2, the control by key location, as seen in Experiment 1 (Figure 5), immediately returned with variable sample location. The choice of the middle key was 94% for the left-key sample and 100% for the right-key sample for Rat 1; for Rat 2, the choice of the middle key was

Table 4

Percentage correct for each sample location in Experiment 2. The first three columns show data when the sample location was fixed (data in parentheses) and when the sample location varied within the session between the left and middle keys; two sessions were scheduled with this condition (Test 1 and Test 2). The next four columns show data for fixed sample location (data in parentheses) and for variable sample location within the session among all three keys; one session (Test 3) was scheduled for each rat. Only Rat 3 had Test 4, which was the same as Test 3, after additional training with the sample on the right side key.

		Sample: left, middle			Sample: left, middle, right			
		Sample location			Sample location			
			Varied			Varied		Varied
Rat	Sample	Fixed	Test 1	Test 2	Fixed	Test 3	Fixed	Test 4
1	Left	(85)	79	77	(81)	56		
	Middle	(84)	85	88	(88)	81		
	Right					50		
2	Left	(80)	72	75	(82)	45		
	Middle	(88)	87	84	(85)	83		
	Right					55		
3	Left	(94)	100	93	(94)	78	(92)	87
	Middle	(92)	85	96	(90)	91	(88)	84
	Right					50	(80)	66

90% for the left-key sample but only 15% for the right-key sample (i.e., Rat 2 primarily pressed the left key when the sample appeared on the right key, as it had in Experiment 1). Rat 3 pressed the middle key on 100% of the trials with the right-key sample, consistent with the pattern seen in Experiment 1.

Because Rat 3 showed some evidence of control by left-key samples during sessions with variable sample locations, this rat was given additional training with the sample on the right key only. For 25 sessions, the sample always appeared on the right side key. By the end of this training, accuracy had reached 80% or higher. The left-key sample location was then repeated for two sessions followed by the middle-key sample location for two sessions. Within-session variable sample location was reintroduced one last time for a single session. Test 4 in Table 4 presents the data for this session together with accuracy (in parentheses) for the immediately preceding sessions with fixed location of each sample. For sessions with fixed sample location, accuracy was 80% or better. With variable sample locations, sample control was evident for samples on the left and middle keys. But for samples on the right key, only 66% of the trials were correct, indicating no control by the sample. Laboratory logistics prevented further training for Rat 3.

DISCUSSION

Experiment 2 demonstrated that sample control could be established for a side-key sample after considerable training. However, sample control was strictly limited to the training conditions. When trials with the untrained right-key sample location were mixed with the trained left- and middle-key sample locations, sample control did not transfer to right-key samples and broke down for left-key samples for Rats 1 and 2 and was weakened for Rat 3. These data suggest that sample control has to be taught separately for each sample location. Experiment 1 similarly showed no evidence of transfer of sample control from the trained middle-key location to the two untrained side-key locations.

The considerable resistance to change that was seen early in training with side-key samples illustrates the strong control brought on by key location in the conditional discrimination paradigm. Rat 1, in particular, impressed the experimenter by completing a full session without a single reinforcement (Session 4) when it consistently pressed the middle key on each trial. The performance patterns for each rat were consistent with

those seen in Experiment 1. Thus, development of consistent key preference on side-key-sample trials was evident first for Rat 1, then for Rat 2, and last Rat 3. In Experiment 2, the consistent key preferences interfered the most for Rat 1 and the least for Rat 3. The difficulties encountered in establishing side-key-sample control in the present experiment show the rigidity of the control exerted by key location. New training was necessary to establish side-key-sample control. Analogous results have been found with pigeons (Jitsumori, Taneya, & Kikawa, 1992; Kuno, Kitadate, & Iwamoto, 1994; B. E. Hesse, personal communication, August, 1992; M. Serge, personal communication, April, 1985). Similarly, 1 of 2 monkeys exposed to the moving-sample procedure (Iversen et al., 1986) required 30 sessions before the accuracy for line stimuli on side-key-sample trials reached just 80%.

The strong key preferences exhibited in this experiment are consistent with similar findings with rats (Iversen, 1993), pigeons (Fersen et al., 1992; Kamil & Sacks, 1972; Lipkens, Kop, & Matthijs, 1988), and monkeys (Iversen et al., 1986; Sidman, 1992). Thus, stimulus location is an important source of competing control in conditional discrimination procedures (see also Mackay, 1991; Sidman, 1992, 1994).

GENERAL DISCUSSION

When the sample and comparison stimuli were relocated in the matching-to-sample procedure after training with fixed stimulus locations, sample control did not transfer from trained to untrained spatial locations. The results are consistent with those reported from similar experiments with monkeys (Iversen et al., 1986) and pigeons (B. E. Hesse, personal communication, August, 1992; M. Serge, personal communication, April, 1985). Furthermore, the results support the growing recognition that the spatial location of the stimuli is a critical parameter in conditional discrimination procedures (D'Amato & Colombo, 1989; Lipkens et al., 1988; Mackay, 1991; Sidman, 1992, 1994; Zentall & Urcuioli, 1993).

Matching-to-sample performance has been accounted for in terms of a single rule (e.g., generalized identity matching), multiple

rules (e.g., if-then relations for each sample stimulus), and stimulus compounds or stimulus–response sequences (see Carter & Werner, 1978; Mackay, 1991). The present results do not support either a single-rule or a multiple-rule account because the same stimuli did not control responding when they appeared in new locations. The results are more congruent with several reports suggesting that matching-to-sample performance in pigeons and monkeys may often be a case of compound stimulus control or specific stimulus–response sequences (e.g., Carter & Werner, 1978; D'Amato, Salmon, & Colombo, 1985; Eckerman, Lanson, & Cumming, 1968; Kamil & Sacks, 1972; Santi, 1978; Sidman, 1992; Wright & Sands, 1981).

With the customary three-key matching-to-sample procedure, the sample appears on the middle key. When the sample is moved to one of the side keys, one comparison stimulus is also moved. This manipulation involves the spatial relocation of the stimuli as well as an exchange of the function of the response keys that display the stimuli. That is, in baseline training, the function of the middle key is to display the first stimulus to be responded to; the function of the side keys is to display the comparison stimuli, one of which is to be responded to next. However, it is not clear whether the failure of transfer results from one, two, or all three changes: sample location, comparison location, and sample-comparison function. To separate each factor entails a different experimental design. A possible way to determine the separate influence of each factor would be to have two rows of three keys. The sample may appear on the middle key in the upper row and the comparison stimuli on the two side keys in the bottom row. After acquisition of matching performance, the sample can be moved in the upper row to a side-key location without changing the location or function of the comparison stimuli. The comparison stimuli can similarly be rearranged in the bottom row without changing the sample location in the upper row. These manipulations also do not switch the sample-comparison function as does the moving-sample procedure with the three-key design. If the matching performance is intact after spatial movement of the stimuli, then switching of the

sample–comparison functions becomes the critical variable.

Generalized identity matching has been obtained in procedures that involve training of many stimulus exemplars in pigeons (e.g., Wright et al., 1988), monkeys (e.g., Overman & Doty, 1980), sea lions (Kastak & Schusterman, 1994), and dolphins (Herman et al., 1989). For example, after lengthy training with hundreds of stimulus pairs, matching performance of pigeons was evident for sets of new stimuli (Wright et al., 1988). The label *generalized identity matching* suggests that the training has established an identity relation between the sample and the correct comparison. An unanswered question, meanwhile, is whether generalized identity matching that is acquired with fixed stimulus locations will also occur with variable stimulus locations. A hint in the literature suggests a possible answer to this question. Kastak and Schusterman (1994) trained 2 California sea lions on a two-choice visual matching-to-sample task with fixed locations of a variety of stimuli. After training, both subjects could perform identity matching with new stimuli, and the authors discussed the results in terms of transfer of an identity matching rule. However, in their discussion, the authors noted briefly that in exploratory studies with the same 2 subjects, matching performance did not transfer to novel arrangements of the testing stimuli (i.e., sample and comparison locations were varied as in the present experiments, and the results of that manipulation were reported to be similar to those in the present experiments). Thus, it is not clear that subjects who show generalized identity matching will also match identical stimuli when novel or even familiar stimuli appear in novel arrangements. The connection between generalized identity matching and control by stimulus location requires further study to elucidate the role of stimulus location in conditional discriminations. Successful transfer of sample control from fixed to variable stimulus locations would indicate that training with many stimulus exemplars may prevent stimulus location from becoming a controlling aspect of the stimuli. On the other hand, a failure to transfer sample control from fixed to variable stimulus locations after training with many stimulus exemplars would indicate that customary acceptance criteria for generalized identity matching require revision.

Generalized identity matching has also been reported after training with just two different training stimuli. In an often-cited study by Oden et al. (1988), 4 experimentally naive infant chimpanzees performed identity matching with new (nonfood) stimuli at the same level as in baseline training (79% to 92% correct). An unheeded aspect of this study is that the stimuli did not occupy different fixed locations. On each trial, the trainer handed the sample object to the subject, who then placed it in a pan (20 cm by 20 cm). Next, the trainer placed the two comparison objects close to the pan, and the subject in turn, when correct, placed the matching object into the pan with the sample. Thus, the subject had to place the sample and the correct comparison at roughly the same location (i.e., in the same pan). In other words, the response to the sample and the response to the correct comparison had the same spatial endpoint coordinates, as opposed to different endpoint coordinates in customary procedures in which sample and comparison stimuli are located on different keys. An unanswered question for procedures that entail actual movement of identical objects to the same location is whether generalized identity matching will occur when sample and comparison objects occupy locations that are different from those used in training.

If a stimulus comes to control performance partly by its location, then it may not control performance when it is moved. Thus, a stimulus, which for the experimenter is *steady light,* may be *steady light on the middle key* for the subject. When the experimenter then presents the identical *steady light* on the left key, it is now a different stimulus for the subject: *steady light on the left key.* If the experimenter's identical stimulus is not responded to by the subject the same way each place it is presented, then the stimulus is not the same when it is moved. That is, the stimulus is not reflexive. Because reflexivity is considered to be an important aspect of equivalence relations (e.g., Sidman et al., 1982), the moving-sample procedure serves as a critical examination of the stimulus control relations that are established in conditional discrimination procedures (see also Iversen et al., 1986; Lipkens et al., 1988; Sidman, 1994).

Table 5

Illustration of the stimulus-location issue with the customary three-key design with the sample always appearing on the middle key and the comparison stimuli on the side keys. Examples show stimulus locations in training of conditional discriminations AB (if A1 then B1, if A2 then B2) and BC (if B1 then C1, if B2 then C2) and in testing of the symmetrical BA and transitive AC relations. Key positions are left (L), middle (M), and right (R). For simplicity, the examples show the correct comparison on the left side key; in actual training and testing, the correct comparison stimulus would appear equally often on either side key across trials. Testing for symmetry of the AB relations exchanges the locations of the sample and comparison stimuli. Testing for transitivity of the AB and BC relations leaves the stimuli in the same locations as in training.

		L	M	R	L	M	R
Symmetry of the AB relation							
Training	Sample		A1			A2	
	Comparisons	B1		B2	B2		B1
Testing	Sample		B1			B2	
	Comparisons	A1		A2	A2		A1
Transitivity of the AB and BC relations							
	Sample		A1			A2	
	Comparisons	B1		B2	B2		B1
Training	Sample		B1			B2	
	Comparisons	C1		C2	C2		C1
Testing	Sample		A1			A2	
	Comparisons	C1		C2	C2		C1

The possibility that stimuli used in conditional discriminations with the three-key procedure become defined with respect to their spatial locations has some implications for work on testing of symmetry and transitivity of conditional relations in nonhuman subjects (e.g., D'Amato et al., 1985; Lipkens et al., 1988; Sidman et al., 1982). Table 5 shows the stimulus locations for each type of test after training using the standard three-key configuration with the sample on the middle key and the comparison stimuli on the side keys. In training the AB relations, the sample stimuli are A1 or A2, and the comparison stimuli are B1 and B2. To test whether the AB relations are symmetrical, B1 or B2 appears on the middle key as the sample, and A1 and A2 appear on side keys as comparison stimuli. Thus, both sample and comparison stimuli change location. If training has established location as part of the definition of the stimuli, then the stimuli are unlikely to maintain control when they appear in a new location (i.e., the controlling stimuli are no longer the same as they were in training). The same issue does not pertain to testing for

transitivity. To test whether the taught AB and BC relations are transitive, A1 or A2 will appear as the sample, and C1 and C2 are the comparison stimuli. Hence, the stimuli occupy the same locations in testing as in training. Experiments with nonhuman subjects report apparent difficulties encountered in obtaining positive evidence of symmetry compared with the relative ease in obtaining positive evidence of transitivity, at least with monkeys as subjects (e.g., D'Amato et al., 1985). This difference could possibly stem from the fact that the stimuli are separated from their trained location in symmetry testing but not in transitivity testing (see also Sidman, 1994). (In testing for equivalence, some or all stimuli are also separated from their location in training, depending on the test design.)

Sidman et al. (1982) suggested that the problem of separating the stimuli from their location in testing may possibly be resolved by designing training procedures so that spatial location does not become a defining feature of the stimuli. Across trials, the stimuli could each appear on any of the key locations. Accurate performance with variable

stimulus location can be acquired by pigeons and monkeys after training, as noted above. Experiment 2 suggested that with extended training, this might also be possible with rats. However, even successful performance with variable stimulus locations does not necessarily mean that the performance is liberated from control by key location (e.g., Kuno et al., 1994; Lipkens et al., 1988). Subjects may merely have acquired several different discriminations. For example, in an experiment with monkeys, in which the location of the comparison stimuli varied among several key pairs, key location was not eliminated as a controlling aspect of the stimuli (Sidman, 1992); rather, the subjects acquired stimulus compounds. The results from the present Experiment 2 similarly suggest that adding new locations to the same stimuli does not necessarily detach the stimuli from their locations. An understanding of the controlling stimulus–response relations in common conditional discrimination procedures therefore faces considerable difficulties. Evidently, experimenters who present identical stimuli at different locations cannot expect that the stimuli are the same for the subject. The identity of the stimuli is for the experimenter, not necessarily for the subject. In such situations, matching-to-sample performance may be a case of mistaken identity, as suggested by Sidman et al. (1982).

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