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TRANSFER OF PIGEONS' MATCHING TO SAMPLE TO NOVEL SAMPLE LOCATIONS

KAREN M. LIONELLO-DENOLF AND PETER J. URCUIOLI

PURDUE UNIVERSITY

This study examined the conditions under which conditional stimulus control by the sample stimuli in three-key matching-to-sample paradigms would generalize across the different possible sample locations. In Experiments 1 and 2, the samples appeared on the left and right side keys during initial training and then on the center key during testing. Transfer of pigeons' matching performances to the center-key samples was evident after both identity and symbolic matching training. In Experiment 3, pigeons trained on symbolic matching with two side-key samples or with a side-key and a center-key sample generally transferred their learned matching performances to those samples when they subsequently appeared in the remaining (novel) location. These results indicate that, when two-choice conditional discriminations are learned with more than one sample location, the visual characteristics of the sample per se predominantly come to control the pigeons' comparison choices. This finding encourages the use of the multiple-location training procedure as a way of reducing control by location, thus providing a more discriminating test of symmetry in animals.

Key words: sample location, matching to sample, transfer of matching, symmetry, key peck, pigeons

Over the past several decades, researchers working with both human and nonhuman animals have investigated the three properties of stimulus equivalence: reflexivity, symmetry, and transitivity (see Sidman & Tailby, 1982). Evidence for all three properties of equivalence relations has been obtained with human subjects (Adams, Fields, & Verhave, 1993; Barnes, McCullagh, & Keenan, 1990; Bush, Sidman, & DeRose, 1989; Devany, Hayes, & Nelson, 1986; Eikeseth & Smith, 1992; Sidman, 1971; Sidman, Cresson, & Willson-Morris, 1974; Spradlin, Cotter, & Baxley, 1973). However, the corresponding data from nonhuman animals have been less encouraging. To date, only one study (Schusterman & Kastak, 1993) has ostensibly demonstrated all three relations in a single subject (a California sea lion).

Some animals have shown evidence for reflexivity, the ability to match a stimulus to itself without explicit reinforcement to do so (e.g., Oden, Thompson, & Premack, 1988). Likewise, there have been a few isolated demonstrations of transitivity (e.g., D'Amato, Salmon, Loukas, & Tomie, 1985), the matching of A to C after being trained to match A to B and B to C (where A, B, and C refer to pairs of samples and comparisons). Evidence for symmetry, the ability to match B samples to A comparisons after being trained to match A samples to B comparisons, has been even more elusive. Despite being trained in a variety of ways, animals most often perform at chance levels of accuracy on tests of symmetry (D'Amato et al., 1985; Hogan & Zentall, 1977; Lipkens, Kop, & Matthijs, 1988; Richards, 1988; Sidman et al., 1982).

The poor performance routinely observed on symmetry tests in nonhuman animals might be attributable to the impact of stimulus location (Sidman, 1992; Sidman et al., 1982). For instance, symbolic or arbitrary matching to sample (MTS) is typically used to train the conditional A-B relation prior to the B-A symmetry test. In this task, a sample is often presented on the center response key of a three-key panel, and the two comparison stimuli are presented on the adjacent (side) keys. Once the training (A-B) relations are learned to a high degree of accuracy, the sample and comparisons are then switched to test for symmetry. In other words, each former comparison stimulus now serves as a sample, and each former sample now serves as one of the comparison alternatives.

It is important to realize, however, that

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Correspondence concerning this article should be addressed to Karen Lionello-DeNolf, Department of Psychological Sciences, Purdue University, 1364 Psychology Building, West Lafayette, Indiana 47907-1364 (E-mail: lionello@psych.purdue.edu).

when the matching stimuli reverse roles in this fashion, they appear in new locations. Specifically, stimuli that have previously appeared only on the center key (i.e., the former samples) now appear on the side keys (as comparisons), and vice versa. This change should pose no problem if matching performances in training are independent of stimulus location. In other words, if animals have learned to match the nominally defined samples to the nominally defined comparisons, then the appearance of these stimuli in new locations should not, by itself, disrupt their performances. Alternatively, if each sample and comparison in training are defined in part by the location at which they appear, then moving them to new locations creates functionally different stimuli. In other words, if the animal learns in training to match ''A on the center'' to ''B on the side,'' then presenting ''B on the center'' and ''A on the side'' involves different stimuli and, thus, does not test for symmetry.

In fact, location *is* part of what rats, monkeys, and pigeons learn about the stimuli in MTS (Iversen, 1997; Iversen, Sidman, & Carrigan, 1986; Lionello & Urcuioli, 1998; Sidman, 1992). For instance, we (Lionello & Urcuioli, 1998) trained pigeons to high levels of accuracy on identity MTS with either vertical and horizontal lines or red and green hues and with samples that always appeared on the center key (and with comparisons on the side keys). Afterwards, we assessed the pigeons' matching performances when the samples were allowed to appear in any of the three locations (left, center, or right) and the comparisons at the remaining two. Although baseline performances with center-key samples remained at high levels of accuracy, performances on trials in which those same samples appeared in new (i.e., side-key) locations dropped to chance (50%). This was true whether the identity task was trained with zero-delay or with simultaneous matching contingencies. Clearly, the performances the pigeons learned in training were not governed by the nominally defined samples and comparisons but were, instead, specific to the locations at which those stimuli appeared.

In a subsequent experiment, we (Lionello & Urcuioli, 1998, Experiment 3) attempted to remove or reduce location as a controlling feature by giving pigeons matching experience with sample and comparison stimuli appearing in multiple locations. Pigeons learned two separate MTS tasks involving different stimuli. In the first, the samples appeared, with equal probability, on any of the three keys; in the second, the samples appeared only on the center key. Once each task was learned to a high degree of accuracy, the samples in the second task were presented, with equal probability, on any of the three keys. Despite their prior multiple-location experience, pigeons performed at chance when the samples from the second task now appeared on either the left or right side key. Moreover, even with repeated testing, they did not learn to match accurately with these ''new location'' samples any faster than pigeons that did not have prior multiple-location experience with other samples. This indicates that experience with samples on all three keys in one task is ineffective in reducing the control that location acquires over performance in another MTS task.

Sidman (1992) has also shown that varying the location of the comparison stimuli from one trial to the next does not eliminate control by location. He trained 2 monkeys on line-identity MTS using a stimulus panel with five response keys. Across trials, the sample was always presented on the center key, but comparisons were presented in six possible location pairs. Sidman found that matching acquisition varied depending on where the comparisons appeared. For example, 1 subject showed a preference for the vertical comparison when the two alternatives were located on the top left and either of the two bottom keys, and a preference for horizontal when the comparisons were located on either the two right-most keys or the two bottom keys. Apparently, instead of learning a single conditional discrimination based on line orientation, the monkeys learned several conditional discriminations based, at least in part, on the location of the comparison stimuli.

Taken together, these results underscore the importance of stimulus location in MTS. Pigeons are unable to match accurately when the samples from a previously learned task appear in novel locations, even when they have multiple-location experience in another MTS task. Likewise, monkeys' choices in identity MTS are affected by where the comparison stimuli appear, even when reinforcement is independent of their location. Thus, moving the matching stimuli to new or different locations seems to create new stimuli and, hence, a new task for the animal to learn.

Nevertheless, there may be other factors that contribute to the poor matching performances observed when otherwise familiar samples appear in new locations. For example, we (Lionello & Urcuioli, 1998) found that pigeons had a bias to peck the closest (i.e., center-key) comparison when samples appeared in a novel side-key location. On side-key-sample trials, over 70% of the pigeons' comparison choices were to the center key. Similarly, 1 of the 2 monkeys in the Iversen et al. (1986) study and 2 of the 3 rats in the Iversen (1997) study showed comparable biases in their choices with side-key samples. This bias can be interpreted in one of two ways. First, it may simply be another indication that the functional stimuli are changed by moving them to new locations. Alternatively, there is the possibility that an unconditioned tendency to choose the closest comparison is itself responsible for the disruption in matching accuracy seen on novel sample-location trials. If so, then preventing or avoiding the bias should permit animals to transfer their learned matching performances to new locations.

Experiments 1 and 2 tested this prediction by training pigeons with samples that appeared on each of the two side keys, and then testing them with those same samples at the center-key location. With center-key test trials, each comparison alternative is equidistant from the sample. Experiment 3 expanded upon this procedure by training pigeons with samples that appeared in any two of the three possible locations and then assessing transfer of matching to the remaining location. Here, the possibility of a response bias in testing varied across training conditions, and we were interested in whether this variation affected pigeons' test performances.

EXPERIMENT 1

One way to eliminate a bias to choose the closest comparison during testing is to train pigeons with left- and right-key samples and then assess transfer of performance to center-key samples. If the bias reported in previous studies (Iversen, 1997; Iversen et al., 1986; Lionello & Urcuioli, 1998) was solely responsible for poor transfer to novel sample locations, then removing the possibility that such a bias could have a differential effect on test performances should increase the chances of observing transfer of matching to new stimulus locations. On the other hand, if pigeons' choices are controlled by the location at which the samples (and comparisons) appear even after training with left- and right-key samples, then their performances on novel center-sample trials should be at chance (cf. Lionello & Urcuioli, 1998).

To test these contrasting predictions and to obtain additional information that would allow us to interpret our results more accurately, Experiment 1 involved two groups of pigeons, both of which were trained on a conditional discrimination with vertical and horizontal lines as samples and comparisons. For both groups, the samples appeared on the left key on half of the training trials and on the right key on the other half, with the two comparison alternatives appearing on the remaining two keys after the sample was turned off. During subsequent testing, both groups were required to match the vertical line sample to the vertical line comparison and the horizontal line sample to the horizontal line comparison (i.e., identity matching) when those samples appeared on the center key.

The two groups differed in the conditional discriminations they learned in training. One group learned identity MTS, the same task that operated on their novel-location trials in testing. The other group, however, learned line oddity from sample (Berryman, Cumming, Cohen, & Johnson, 1965). For this group, their reinforced choices during training were exactly the opposite of those required on the novel center-key trials during testing.

The inclusion of the oddity-trained group was driven primarily by the necessity to have a comparison group to interpret properly any evidence that we might obtain for possible transfer across locations in the identity group. Considering our previous findings of essentially no transfer of matching to novel locations by pigeons (Lionello & Urcuioli, 1998), we anticipated the possibility that any transfer observed in this experiment would not be immediately apparent but, rather, would appear as a ''savings effect'' over repeated reinforced test trials and test sessions. If so, then it is imperative to determine whether relatively fast acquisition of line-identity matching with novel center-key samples results from a prior training history on line-identity matching (with left- and right-key samples) or simply reflects ''nonspecific'' factors (e.g., prior experience with any matching task whatsoever, prior discriminations involving the particular line stimuli used on the test trials, etc.). The oddity group nicely equates for these nonspecific factors.

Thus, if our multiple-location training procedure effectively reduces the control that stimulus location might otherwise exert, and it eliminates a response bias confounding effect on the test trials themselves, then we should see faster acquisition of line-identity matching with the center-key samples in the identity-trained group than in the oddity-trained group. Indeed, a stronger prediction is that multiple-location training will yield relatively immediate transfer to the new locations, in which case the identity-trained group should match well above chance and the oddity-trained group should match well *below* chance on the initial test session.

Alternatively, if our training procedure fails to reduce control by stimulus location such that the samples that appear on the center key during testing are functionally different from the same stimuli when they appear as left- and right-key samples, then the two groups should not differ from one another in their test-trial performances, even with repeated reinforced testing. This is a strong prediction but one that we based on the fact that in Lionello and Urcuioli (1998, Experiment 3), pigeons with prior experience with multiple-location samples did not learn to match any faster with new samples in new locations than pigeons without any such prior experience.

Method

Subjects. The subjects were 10 White Carneau retired breeders obtained from the Palmetto Pigeon Plant. Each pigeon had previous MTS experience with center-key samples involving different stimuli than what were used here. Birds were maintained at 80% of their free-feeding weights and obtained their daily food allotment during the experimental session. Housing consisted of stainless-steel wire-mesh cages that were contained in a room with a 14:10 hr light/dark cycle. Water and pigeon grit were freely available in the home cage. Prior to the start of the experiment, the pigeons were divided into two groups of five.

Apparatus. The apparatus consisted of one standard conditioning chamber (BRS/LVE Model SEC-002) with a BRS/LVE Model PIP-016 three-key panel. Each response key measured 2.5 cm in diameter and was located 5.7 cm from the adjacent keys, forming a horizontal row 7.5 cm from the top of the panel. Each key was equipped with an inline projector mounted from behind. Stimuli were three black vertical or horizontal lines on a white background (BRS/LVE Pattern 715). The food hopper was located 9 cm below the center response key, and its opening measured 5.8 cm by 5.8 cm. A GE 1829 houselight was located at the top center of the panel and provided illumination of the chamber during each trial. A blower fan mounted on the outside of the chamber provided ventilation and masking noise. Data were collected and experimental events were controlled by a Gateway 2000 386SX/25 computer.

Procedure. Each bird was given 1 day of preliminary training to peck the vertical and horizontal line stimuli on the center key and 1 day of training to peck those same stimuli on both the center and the side keys. Each session of preliminary training consisted of 60 trials, each separated by a 10-s intertrial interval (ITI). At the start of every trial, a stimulus appeared on one of the response keys and remained lit until a peck was made to it. Once pecked, the stimulus was terminated and the food hopper was raised for 3 s. Both the vertical and horizontal line stimuli appeared an equal number of times in a session and, when stimuli could appear on all three keys, each stimulus was presented an equal number of times on each key. During the next five sessions, the required number of pecks to each stimulus when it appeared on the center key was increased from 1 to 10.

Each bird was then trained to match vertical and horizontal line samples to vertical and horizontal line comparisons. Trials began with a presentation of either the vertical or the horizontal sample on either the left or right response key. Ten pecks to the sample turned it off and resulted in comparison presentation on the remaining two response keys. Additional pecks to the darkened sample response key once the comparisons were presented had no programmed consequences. A single peck to either comparison terminated both stimuli. Correct comparison choices were followed by access to the raised food hopper, whereas incorrect choices turned off the houselight for a period of time equal to the reinforcement duration (i.e., timeout). Group Identity was trained to match vertical and horizontal line samples to vertical and horizontal line comparisons, respectively (identity matching). Group Oddity was trained to match the same samples to the opposite comparisons. In other words, for this latter group, pecking the horizontal comparison after the vertical sample and pecking the vertical comparison after the horizontal sample were reinforced (oddity from sample).

After reinforcement or timeout for comparison choice, a 10-s ITI began, the first 9 s of which were spent in darkness. The houselight was then turned on for the last second of the ITI and remained lit throughout the subsequent trial. Reinforcement was varied between 1.8 and 6 s across sessions in such a way as to maintain each bird at its 80% weight. Sessions consisted of 96 trials in which each line stimulus appeared as a sample an equal number of times in the left and right locations. Sessions were conducted 6 days per week. Training for each bird was continued for a minimum of 10 sessions and until it matched correctly on 90% or more of all trials for five of six successive sessions.

Once this acquisition criterion had been reached, 10 sessions of reinforced testing began. Each session consisted of 64 baseline training trials intermixed with 32 center-key test trials. Each successive block of 24 trials in a session contained eight test trials intermixed with 16 baseline trials. Baseline trials for both groups consisted of left- and right-key samples, with the same reinforcement contingencies for comparison choice as during training. On test trials, a vertical or horizontal sample appeared on the center key with comparisons appearing on the left and right side keys after 10 pecks to the sample. For both groups, choosing the identical (i.e., matching) comparison was reinforced on all test trials.

Statistical analyses. Statistical evaluation of overall effects within and between groups initially involved analysis of variance (ANOVA). Where appropriate, these were followed by post hoc contrasts on the group means using the methods, tabled *F* values, and inferential techniques described by Rodger (1975a, 1975b). Type I error rate was set at .05.

Results

Group Identity reached criterion levels of performance in training somewhat more quickly (20 sessions; range, 11 to 30) than did Group Oddity (28 sessions; range, 11 to 50), although this difference was not significant, $F(1, 8) = 1.07$. More important, there were no significant between-group differences in matching accuracy by the end of training. Averaged over the last 5 days of training prior to testing, baseline accuracies were 94% and 93% for Groups Identity and Oddity, respectively, $F(1, 8) = 0.5$.

Individual data from the first novel-location test session are shown in Figure 1. On baseline trials, 4 of the 5 Group Identity birds maintained an accuracy of at least 89% correct; accuracy for the remaining bird was 72%. For Group Oddity, all 5 birds maintained accuracies at or above 90%. Overall, there was no between-group difference in baseline performances: 90% and 96% correct, on average, for Groups Identity and Oddity, respectively, $F(1, 8) = 1.6$.

On the novel-location (test) trials, all birds in Group Identity matched above the level expected by chance alone (range, 60% to 87%). By contrast, accuracy on these trials was well below chance for all 5 birds in Group Oddity (range, 16% to 22%). Averaged test-trial accuracies in Groups Identity and Oddity were 79% and 19%, respectively, a difference that was statistically significant, $F(1, 8) = 110.35$.

The top portion of Table 1 shows accuracy on the first-session test trials as a function of sample stimulus for individual subjects. For Group Identity, 2 birds matched above 80% correct with both sample stimuli, 2 matched at or above 69%, and the remaining bird matched at 69% with one sample and at chance with the other sample stimulus. For Group Oddity, accuracy was less than 40% correct for each sample for all 5 birds. For 3

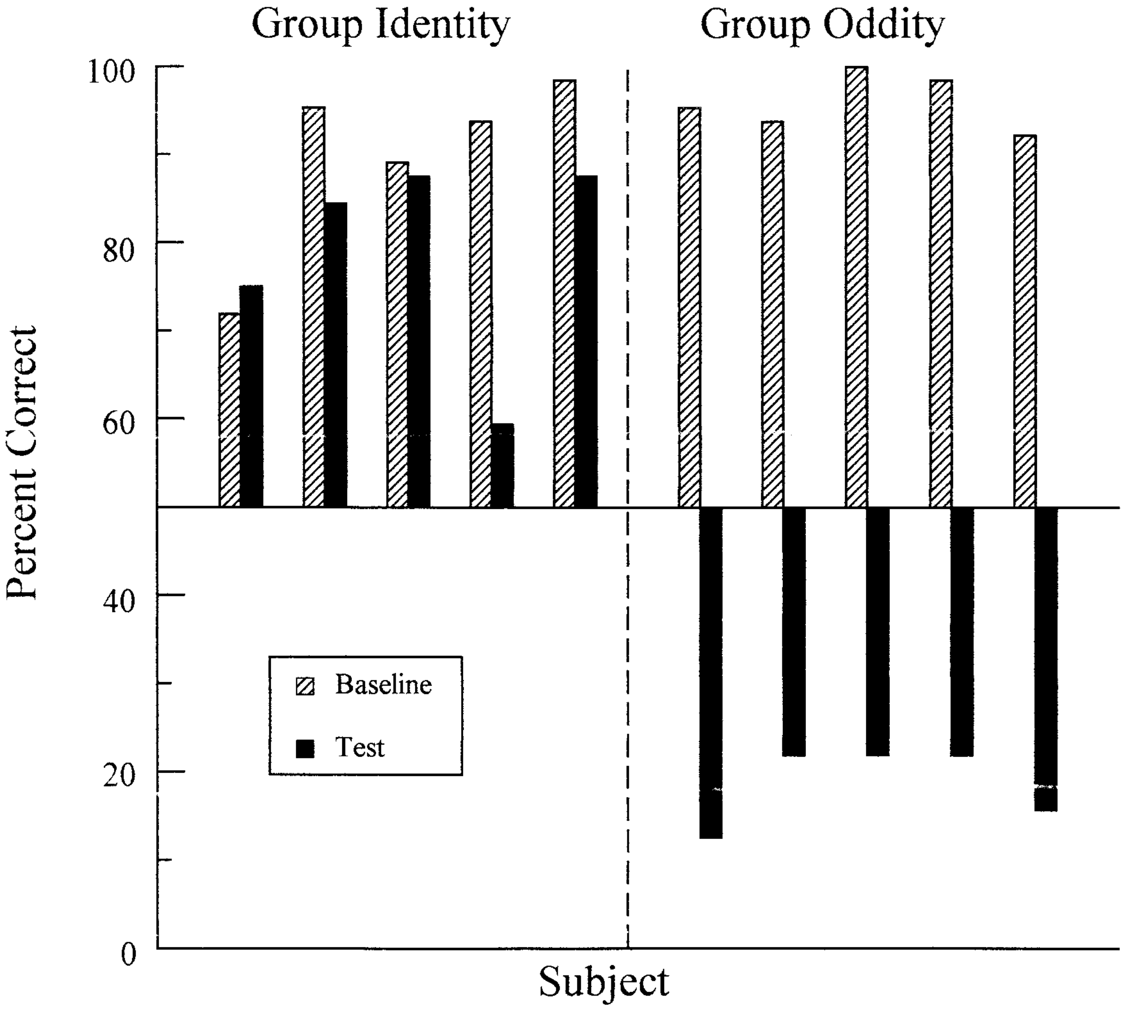

Fig. 1. Percentage correct by trial type on the first test session for each subject in Experiment 1. The striped bars show accuracy on trials in which the sample appeared in the familiar left or right training location (baseline). The solid bars show accuracy on trials in which the sample appeared in the novel, center-key location (test).

Table 1

Test-trial accuracy (percentage correct) as a function of sample stimulus for individual birds on the first test session in Experiments 1 and 2.

Experiment 1	ID1	ID2	ID3	ID4	ID5	OD1	OD2	OD3	OD4	OD5
Vertical	81	75	94	50	88	13	19	38	31	25
Horizontal	69	94	81	69	88	13	25	6	13	6
Experiment 2	CS1	CS2	CS3	CS4	CS5	IN1	IN2	IN3	IN4	IN5
Blue	69	100	81	88	50	25	0	6	19	13
Yellow	63	75	94	81	56	0	38	13	38	0

Note. ID = identity, OD = oddity, CS = consistent, IN = inconsistent.

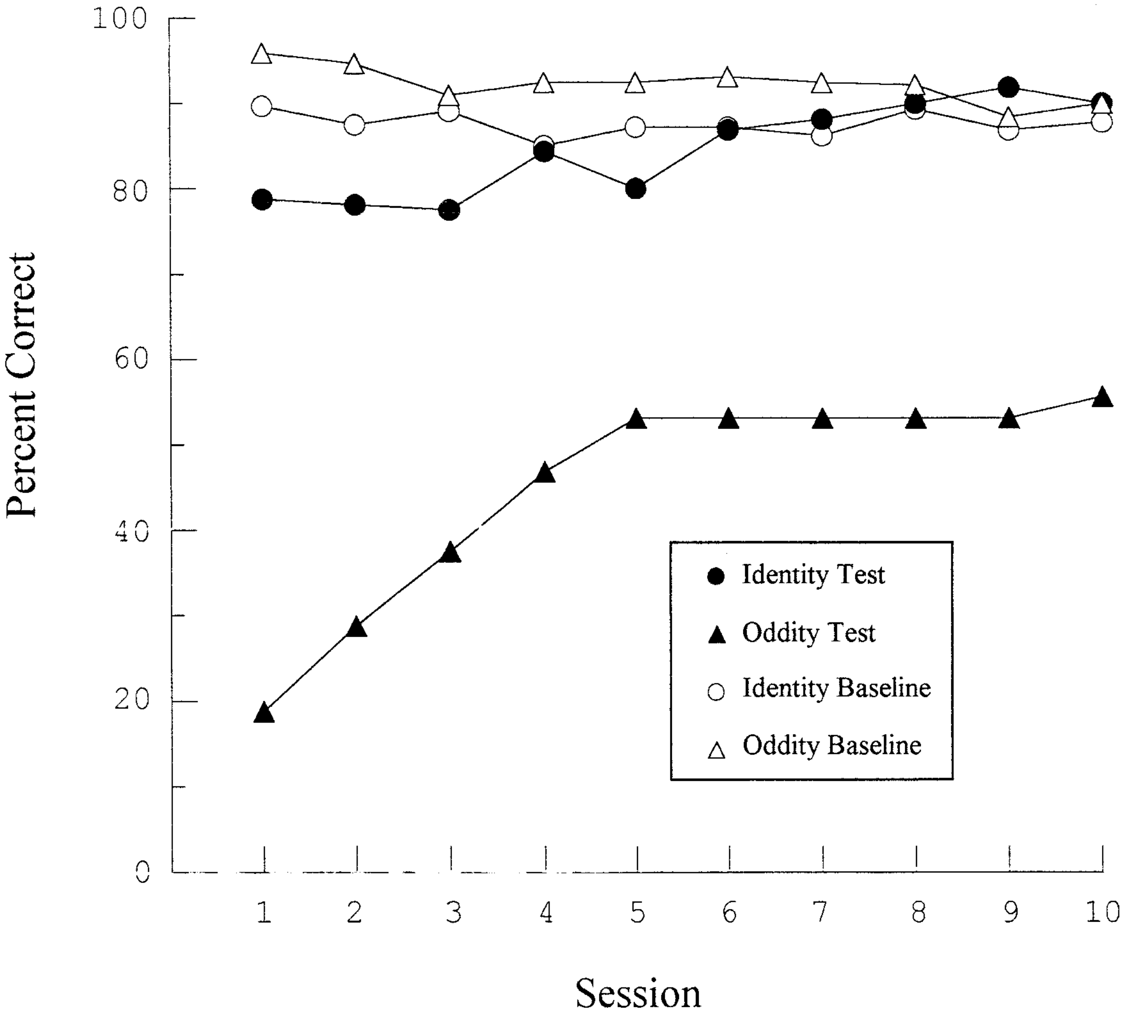

Fig. 2. Percentage correct for each group on baseline and test trials for the 10 test sessions in Experiment 1.

birds, accuracy did not exceed 25% correct for either sample. The general pattern of results exhibited across birds indicates that the control exerted by the sample stimuli in their new location was the same as, or very similar to, that established during training (cf. Sidman, 1980).

Figure 2 shows averaged performances of both groups over all 10 test sessions. Group Identity continued to match at accuracy levels above chance on center-sample test trials. By contrast, Group Oddity's performance on test trials did not increase above chance (50%).

Discussion

The results of Experiment 1 indicate that training with left- and right-key samples reduces the control that sample location would normally exert over comparison choice (cf. Lionello & Urcuioli, 1998). Most pigeons trained on identity MTS with side-key samples continued to choose the matching comparison at levels well above chance when those same samples now appeared on the center key. All pigeons trained on oddity from sample with side-key samples continued to choose the odd comparison on center-key-sample test trials, producing accuracy well below chance on these trials. With repeated testing, Group Oddity continued to choose the odd comparison on at least 50% of the test trials, even though reinforcement was consistently delivered for choosing the identical comparison on center-key-sample trials.

These results stand in stark contrast to our earlier findings (Lionello & Urcuioli, 1998), which showed that pigeons do not transfer their learned matching performances to new locations after training with just a single (i.e., a center-key) sample location. We had interpreted our previous findings as evidence that moving familiar samples to new locations effectively creates new stimuli for pigeons, thus yielding a functionally novel matching task. Applying the same analysis here, if the location of the left- and right-key samples in the current study had likewise exerted control over the performances learned in training, then moving those samples to the center key in testing would likewise produce new stimuli and, as a result, functionally new tasks for both groups. By this reasoning, both groups should have performed similarly—and at accuracy levels close to chance—on their center-key-sample test trials, even though the matching contingencies on the test trials were unchanged in one group (identity) but reversed in the other (oddity). Instead, the choices of both groups on the center-key-sample test trials were consistent with the matching contingencies they had experienced during training, yielding their dramatically different test-trial accuracies.

These results are important because they demonstrate transfer of learned performance to a novel sample location, something that previous reports have failed to show (e.g., Iversen, 1997; Iversen et al., 1986; Lionello & Urcuioli, 1998). Again, these previous studies had indicated that physically identical stimuli are not the same to animals when they appear in new locations. By contrast, the present results suggest that the vertical and horizontal line stimuli were functionally the same stimulus to the pigeons, no matter where they appeared. In addition, our data suggest that training with samples that appear on each side key and testing with center-key samples in order to remove the possibility of a closest key bias enhance the chances that the matching stimuli themselves will control the pigeons' performances.

EXPERIMENT 2

The purpose of Experiment 2 was twofold. First, we wanted to replicate the general findings of Experiment 1 in view of the contrast they pose relative to previous findings (e.g., Iversen, 1997; Iversen et al., 1986; Lionello & Urcuioli, 1998). Second, we wished to determine whether the multiple-location training procedure would also reduce control by location in symbolic MTS, the task on which subjects are trained in studies of (i.e., prior to testing for) symmetry.

To that end, two groups were trained to match hue samples that appeared on the left and right side keys to line comparisons. In testing, the hue samples were presented on the center key as well. For one group, choices of the line comparisons consistent with its side-key-sample training were reinforced. For the other group, choices of the comparisons inconsistent with side-sample training were reinforced. If the results of Experiment 1 are replicable in symbolic MTS, then the former group should show above-chance accuracy on the center-key-sample test trials, whereas the latter group should match at below-chance levels of accuracy.

Method

Subjects and apparatus. Ten White Carneau retired breeders obtained from the Palmetto Pigeon Plant were used. Subjects had experimental histories identical to the pigeons in Experiment 1 and, prior to the start of the experiment, were divided into two groups of five. The apparatus was identical to that used in Experiment 1, except for the addition of blue and yellow homogeneous fields to each of the three inline projectors.

Procedure. Each bird received preliminary training to peck the hue and line stimuli similar to that of Experiment 1. Immediately following preliminary training, birds in both groups were trained to match blue and yellow samples to vertical and horizontal comparisons, respectively. Samples appeared an equal number of times on the left and right response keys. Comparisons appeared on the remaining two keys and were counterbalanced with respect to them. All other aspects of the MTS procedure were identical to those in Experiment 1.

After each bird reached an acquisition criterion of 90% correct or better for five of six successive sessions, it was then tested for 10 sessions during which each hue sample could appear on all three keys. As in Experiment 1, each session consisted of 64 baseline trials intermixed with 32 test trials. As before, each successive block of 24 trials contained eight test trials intermixed with 16 baseline trials. For left- and right-key samples, the bird's training contingencies remained in effect. When the sample appeared on the center key, choices of vertical after a blue sample and horizontal after a yellow sample were still reinforced for Group Consistent. For Group Inconsistent, however, choices of horizontal after the blue center-key sample and vertical after the yellow center-key sample were reinforced. For these latter birds, the matching contingencies on test trials were the opposite of those in effect on left- and right-key sample (baseline) trials.

Results and Discussion

The birds in Groups Consistent and Inconsistent reached criterion levels of accuracy on the acquisition task, on average, in 18 and 20 sessions, respectively (ranges of 11 to 27 and 12 to 25 for Groups Consistent and Inconsistent, respectively). There was no significant difference between the two groups, $F(1, 8) = 0.15$, nor were there differences in their performances over the last five sessions prior to testing: 95% and 94% for Groups Consistent and Inconsistent, respectively, $F(1, 8) = 0.41$.

Individual data from the first test session are shown in Figure 3. All 10 birds maintained high levels of accuracy on baseline trials, averaging 96% and 92% in Groups Consistent and Inconsistent, respectively, $F(1, 8) = 0.63$. On center-sample test trials, 3 of the Group Consistent birds matched well above chance (range, 84% to 88%), 1 bird matched correctly on 66% of the test trials, and the remaining bird matched at 53%. All 5 Group Inconsistent birds performed at accuracy levels well below chance (range, 6% to 28%). Average test-trial accuracies were 76% and 15%, respectively, in Groups Consistent and Inconsistent. This difference was significant, $F(1, 8) = 194.91$.

Accuracy by sample stimulus for individual birds on the first test session is shown in the bottom portion of Table 1. Three of the 5 birds in Group Consistent maintained accuracy levels of at least 75% correct with both sample stimuli and, for 2 of these, accuracy was greater than 80% with each sample. One bird matched in the 60% range with both samples, and the remaining bird matched at accuracy levels close to chance. For 3 of the 5 birds in Group Inconsistent, accuracy with one sample was 0% and accuracy with the remaining sample ranged from 13% to 38%. For the remaining 2 birds, accuracy levels ranged from 6% to 38%.

Figure 4 shows averaged data for both groups over all 10 test sessions. With repeated testing, Group Consistent continued to match in the 80% accuracy range on center-sample test trials although overall test-trial performances in this group never reached the level of baseline performances with the left- and right-key samples. Accuracy on center-sample trials in Group Inconsistent increased noticeably over sessions but did not exceed chance (50%) levels.

These results systematically replicate the findings of Experiment 1 and suggest that the location of the sample stimulus was, again, a relatively minor factor in the birds' comparison choices. Instead, the samples (and comparisons) themselves, and not their location, primarily governed the birds' symbolic matching performances. In other words, following the multiple-location training, when the blue and yellow samples appeared at a novel (center) location, they were functionally the same stimuli as those that appeared at the side locations. These findings indicate, once again, that training with samples on the left and right keys reduces the control normally exerted by stimulus location.

EXPERIMENT 3

Experiment 3 investigated which aspect of the modified MTS procedure was responsible for reducing control by sample location. In the first two experiments, training was conducted with samples that appeared on the left and right side keys in order to avoid any bias to peck a closest key comparison on test trials in which the sample appeared in a new location. With the center key serving as the new location, each comparison is equidistant from the sample. However, it is also possible that the results of Experiments 1 and 2 could have been due to training with any two sample locations rather than locations that would avoid a closest key bias on test trials.

Thus, Experiment 3 investigated whether the closest key bias observed in previous experiments (e.g., Lionello & Urcuioli, 1998)

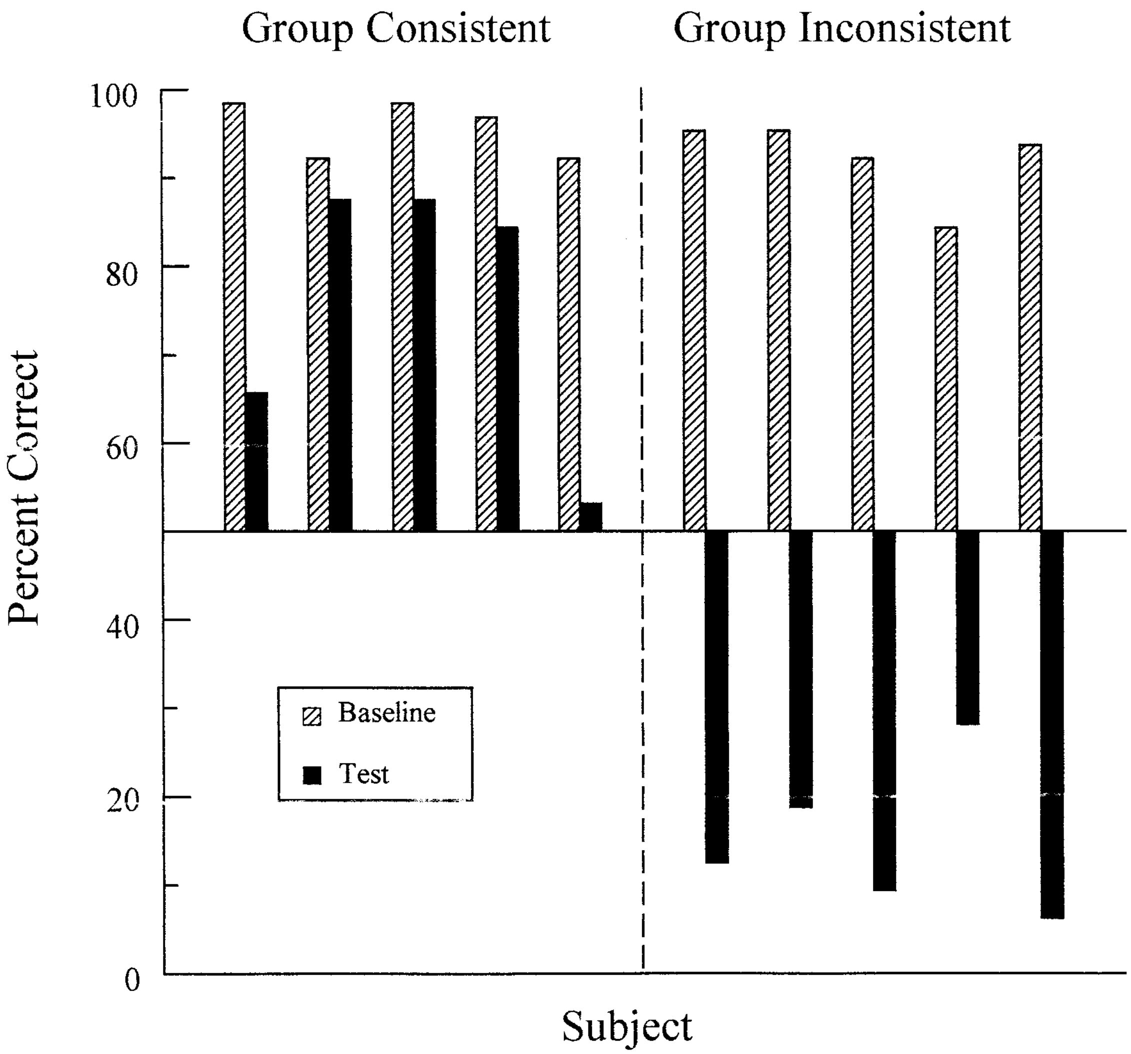

Fig. 3. Percentage correct by trial type on the first test session for each subject in Experiment 2. The striped bars show accuracy on trials in which the sample appeared in the familiar left and right (baseline) locations. The solid bars show accuracy on trials in which the samples appeared on the center key (test).

was the source of the birds' failure to transfer performance to samples in new locations or simply a symptom of location control. If eliminating the possibility of a closest key bias was the source of the transfer in Experiments 1 and 2, then transfer would not be expected in a group trained with samples that appeared at one side-key location on half of the trials and at the center location on the remaining half. The reason is that on test trials in which the sample appears at the novel location (the remaining side key), a closest key bias is possible because one comparison will be located on the adjacent center key. On the other hand, if training with two locations is sufficient to reduce control by stimulus location, transfer of matching to a new location would still be expected in such a group.

Experiment 3 employed three groups, two trained with samples that appeared on the center and one side key (either the left or the right) and the third with samples that appeared on only the side keys. During subsequent testing, samples were presented on the remaining ("novel") key. As in Experiment 2, each group was split into consistent and inconsistent transfer groups.

If a closest key bias prevents accurate per-

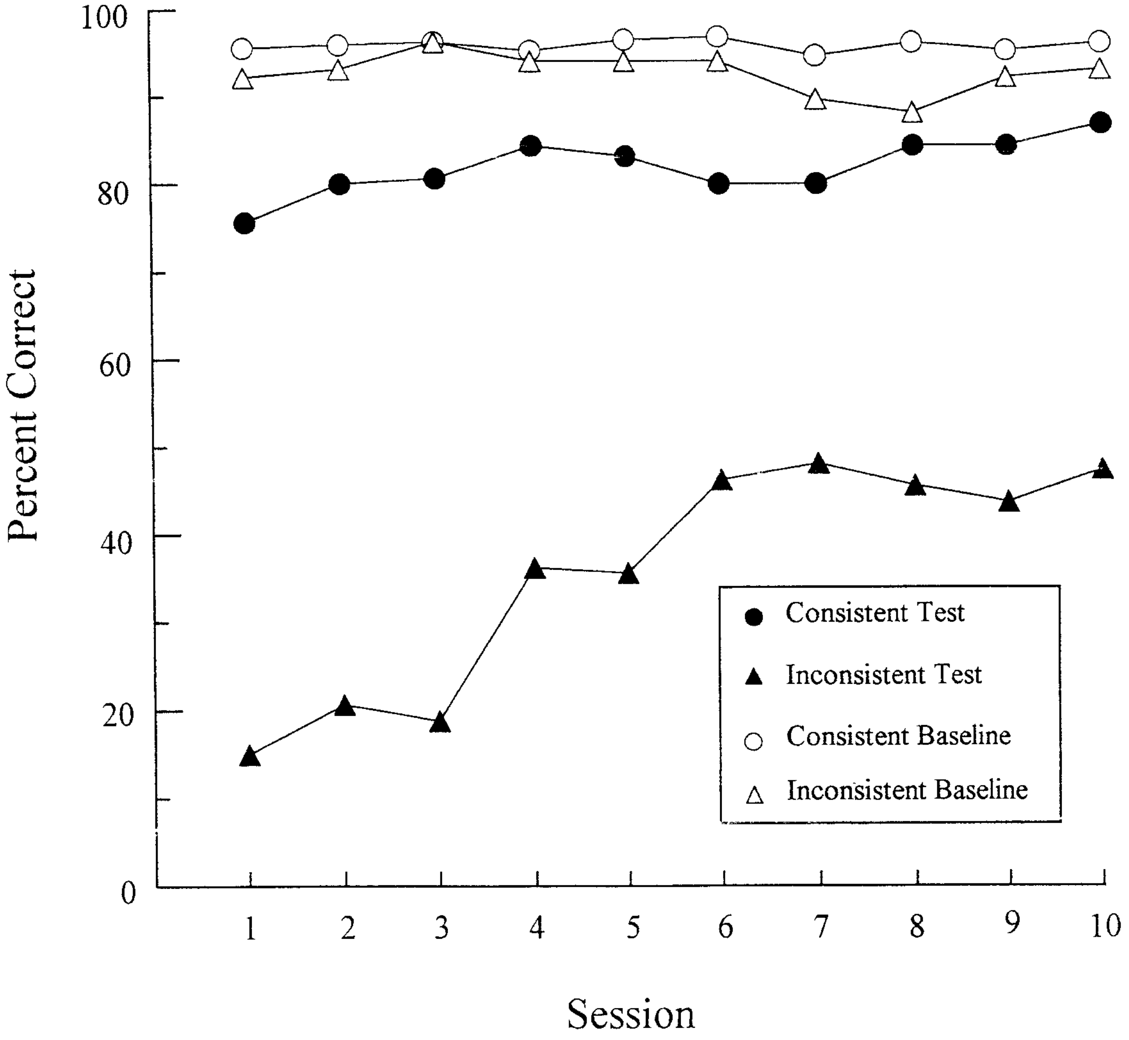

Fig. 4. Percentage correct for each group on baseline and test trials for the 10 test sessions in Experiment 2.

formance when samples are moved to new locations, then transfer of matching should be seen only when pigeons are trained with samples that appear on the two side keys. By contrast, pigeons trained with samples appearing on one side key and on the center key should not transfer their performances to the remaining side-key (novel) sample location because with that location, a center-key bias would drive matching accuracy toward chance. Alternatively, if training with two sample locations per se reduces control by stimulus location, all pigeons should transfer their matching performances to their novel location. Specifically, the three consistent subgroups should match at accuracy levels above chance and the three inconsistent subgroups should match at accuracy levels below chance.

Method

Subjects and apparatus. Twenty-four White Carneau retired breeders obtained from the Palmetto Pigeon Plant were used. Their experimental histories, their housing conditions, and the apparatus in which sessions were conducted were identical to those in Experiments 1 and 2, with the exception that a second conditioning chamber was used. Prior to the start of the experiment, the birds were divided into six groups of four, with half ran-

Table 2

Location of the sample stimuli for each group in Experiment 3.

	Sample location	
Group	Training	Testing
Center	Left and right	Center
Left	Right and center	Left
Right	Left and center	Right

domly assigned to one chamber and the other half to the other chamber.

Procedure. Each bird received preliminary training identical to that of Experiment 2. Immediately following preliminary training, birds were given MTS training in which choices to vertical and horizontal line comparisons were reinforced after blue and yellow samples, respectively. Table 2 shows the locations of the samples during training and testing for the birds in each group. Birds in Group Center received training with left- and right-key samples and were tested with center-key samples. Birds in Group Left were trained with right- and center-key samples and were tested with left-key samples. Finally, birds in Group Right were trained with left- and center-key samples and were tested with right-key samples. MTS training for each bird was continued until it reached a criterion of 90% correct or better accuracy for five of six successive sessions. All other aspects of the MTS procedure were identical to those in Experiments 1 and 2.

Testing began on the session after each bird met the acquisition criterion. In each of 10 test sessions, the two sample stimuli appeared on the remaining (novel) key on 32 of the trials and in their training locations on the remaining 64 trials. Each successive block of 24 trials contained eight test trials intermixed with 16 baseline trials. On the latter (baseline) trials, the training contingencies remained in effect. On novel-location test trials, the consistent groups received food reinforcement for choosing the same comparison stimulus following each sample as in training (e.g., vertical after blue and horizontal after yellow), whereas the inconsistent groups received reinforcement for choosing the opposite comparisons vis-à-vis the reinforced choices on the baseline trials (e.g., horizontal after blue samples and vertical after yellow samples).

Table 3

Days to reach acquisition criterion and mean accuracy for five sessions prior to testing for each group in Experiment 3.

Group	Days to criterion	Baseline accuracy
Center		
Consistent	27	91%
Inconsistent	22	92%
Left		
Consistent	21	95%
Inconsistent	13	95%
Right		
Consistent	12	95%
Inconsistent	12	95%

Results

Table 3 shows the number of sessions to the acquisition criterion for each group, as well as its baseline accuracy averaged over the last five training sessions. Each group's data have been subdivided according to whether birds were later tested with novel-location matching contingencies that were consistent or inconsistent with the baseline contingencies. On average, Group Center required more sessions (24.5; range, 11 to 40), to reach criterion in acquisition than did Groups Left and Right (17; range, 6 to 34; and 12; range, 6 to 17, respectively), but these between-group differences were not significant, $F(5, 18) = 1.45$. The greater number of days to criterion for Group Center was attributable to 3 birds (2 in the consistent subgroup and 1 in the inconsistent subgroup) that did not meet the acquisition criterion after 40 training sessions. Nonetheless, they were advanced to the test phase because their accuracies were both high and stable (87% to 88%). More important, all groups were matching at similarly high levels of accuracy by the end of training (range, 91% to 95%); there were no significant differences between groups, $F(5, 18) = 2.35$.

Figures 5, 6, and 7 show individual data for Groups Center, Left, and Right, respectively, during their first novel-location test session. The left and right panels of each figure show data for birds tested in the consistent and the inconsistent conditions, respectively. Accuracy on baseline trials remained high for birds in all three groups (range, 81% to 98%). All

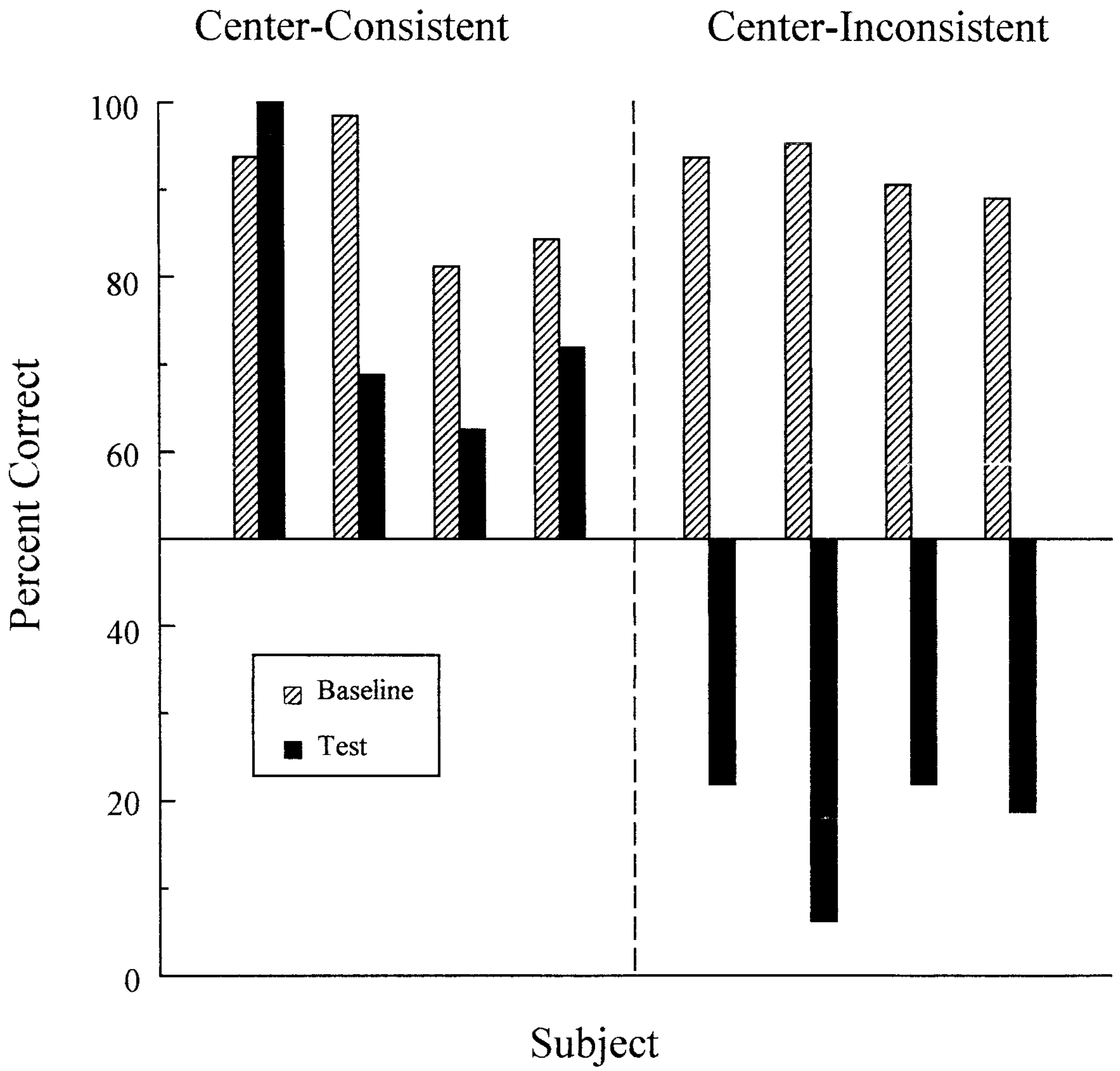

Fig. 5. Percentage correct by trial type on the first test session in Experiment 3 for each subject in Group Center.

birds except for 2 in Group Center-Consistent matched at an accuracy of 89% correct or better on these trials. The 2 remaining birds matched correctly on 81% and 84% of their baseline trials.

On novel-location test trials, every bird in the consistent conditions except 1 chose the correct (reinforced) comparison on greater than 50% of the test trials, regardless of the location of the novel sample. Indeed, 1 of these birds (in Group Center) was more accurate on its novel-location trials than on its baseline trials, choosing the correct comparison on 100% of all test trials. Matching accuracies for birds in the inconsistent conditions were more variable across groups, but were nonetheless appreciably lower than for those in the consistent conditions. For example, the birds in Group Center-Inconsistent correctly chose the reinforced comparison on only 6% to 22% of their test trials. Similarly, 3 of the 4 birds in Groups Left-Inconsistent and Right-Inconsistent matched below chance levels (range, 28% to 46%).

Table 4 shows the average matching accuracy for each group on its first test session. Average baseline accuracies ranged from 89% to 97% across groups, and did not differ sig-

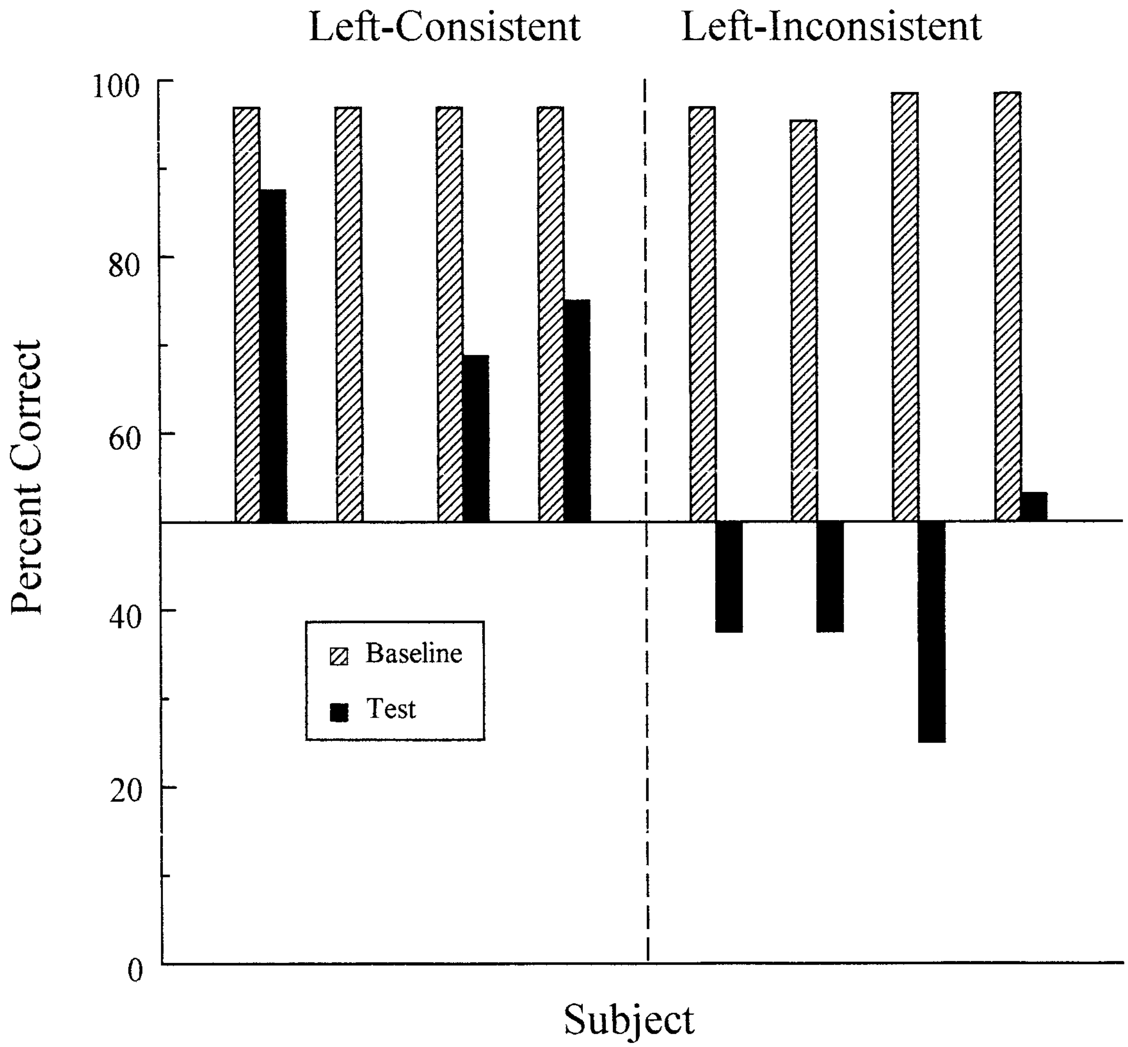

Fig. 6. Percentage correct by trial type on the first test session in Experiment 3 for each subject in Group Left.

nificantly among them, $F(5, 18) = 1.99$. On test trials, each group chose the correct comparison more often when tested in the consistent condition than when tested in the inconsistent condition, $F(1, 6) = 206.40$, 28.23, and 260.38 for Groups Center, Left, and Right, respectively.

We also compared accuracy on test trials across groups; in other words, with respect to the novel location (left, center, or right) of the samples. For birds tested in the consistent condition, there were no significant between-group differences in accuracy as a function of novel sample location, $F(2, 9) = 0.47$. However, for birds tested in the inconsistent condition, test-trial accuracy was lower for Group Center than for Groups Left and Right, $F(2, 9) = 8.16$, which did not differ from each other, $F(2, 9) = 0$.

Table 5 shows accuracy by sample stimulus on the first test session for each pigeon. Eight of the 12 pigeons tested in the consistent condition chose correctly on 10 or more of the 16 test trials with each sample stimulus (i.e., at accuracy levels of 63% or greater). Some of the consistent birds showed a relatively large accuracy difference (25% or greater) across the two samples (e.g., LC1, LC3, RC3, and RC4), but most performed similarly across trial types. For the pigeons tested in

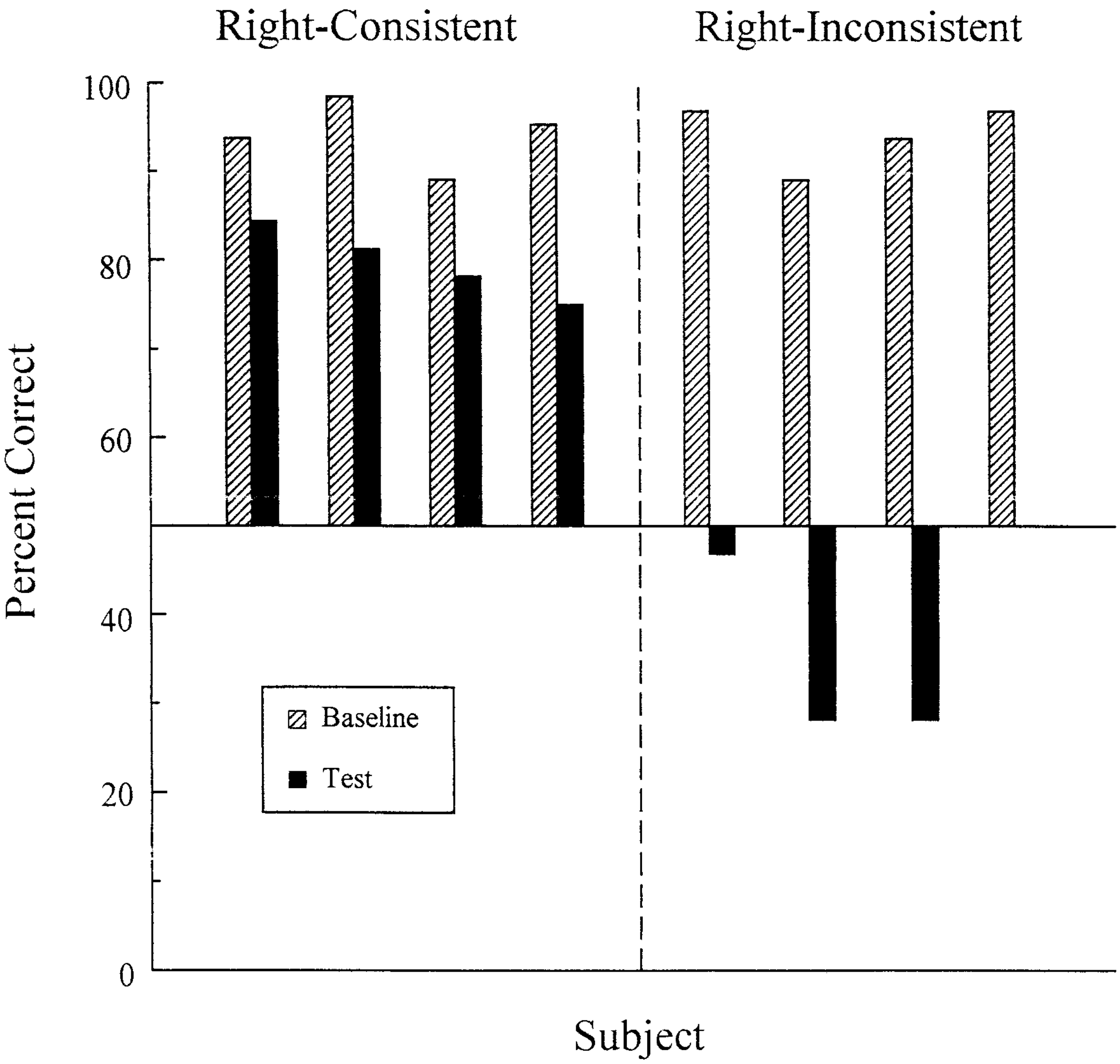

Fig. 7. Percentage correct by trial type on the first test session in Experiment 3 for each subject in Group Right.

Table 4

Test-session accuracy (percentage correct) for all groups in Experiment 3.

Group	Baseline	Test
Center		
Consistent	89	76
Inconsistent	92	17
Left		
Consistent	97	64
Inconsistent	97	38
Right		
Consistent	94	80
Inconsistent	94	38

the inconsistent condition, 7 matched at or close to chance levels with one or both samples; all were in Groups Left and Right. Despite this, choice accuracy with the other sample was well below chance for 4 of these birds. All 4 inconsistent birds in Group Center matched well below chance with both samples.

The results of repeated testing (not shown) indicate that test-trial accuracy for all birds in the consistent conditions increased over sessions such that there were no significant differences relative to baseline trials by the second (Groups Center and Right) and sixth (Group Left) sessions, $F(1, 6) = 0.92$, 2.3, and

Table 5

Test-trial accuracy (percentage correct) as a function of sample stimulus for individual birds on the first test session in Experiment 3.

	Group Center							
	CC6	CC7	CC8	CC9	CI6	CI7	CI8	CI9
Blue	100	63	69	63	19	6	31	25
Yellow	100	75	56	81	25	6	13	13
	Group Left							
	LC1	LC2	LC3	LC4	LI1	LI2	LI3	LI4
Blue	100	50	81	75	50	50	25	50
Yellow	75	50	56	75	25	25	25	56
	Group Right							
	RC1	RC2	RC3	RC4	RI1	RI2	RI3	RI4
Blue	88	75	94	50	44	19	50	50
Yellow	81	63	63	100	50	44	6	50

1.6, respectively. By contrast, test-trial accuracy for birds in the inconsistent conditions did not increase above chance levels, even after 10 test sessions.

Discussion

The results of this experiment indicate that the transfer effects seen in Experiments 1 and 2 were primarily the result of training with two sample locations rather than removing the possibility of a closest key bias in testing. If circumventing a potential bias by pigeons to peck the closest comparison key on novel sample-location trials yielded transfer of matching performance to the center-key location in Experiments 1 and 2, then only the pigeons trained with the two side-key samples in this experiment (viz. Group Center) should have shown transfer. In fact, all three groups continued to choose between the comparisons on their test trials as they had in training, regardless of which two sample locations had been used in training and which location was novel in testing. This was shown by the fact that the consistent groups generally matched at accuracy levels above chance, whereas the inconsistent groups generally matched at or below chance, although the individual-subject data (see Table 5) indicate that the strongest effects in the inconsistent condition occurred when the pigeons were tested with center-key samples (i.e., in Group Center).

Groups Left and Right did show a slight bias to choose the closest key on their test trials: 60% of their choices were to the comparison stimulus closest to the sample (i.e., on the center key). Despite the slight bias, test-trial accuracy in the two consistent subgroups by the end of testing was indistinguishable from accuracy on baseline trials. Conversely, test-trial accuracy in the two inconsistent subgroups did not exceed chance (50%) even after 10 reinforced sessions.

Altogether, these results indicate that MTS training with *any* two sample locations is sufficient to reduce the control that stimulus location would normally exert over performance (cf. Lionello & Urcuioli, 1998). Stated otherwise, training with multiple sample locations increases the likelihood that pigeons will learn to match ''blue to vertical'' rather than ''blue on the center to vertical on the side.''

GENERAL DISCUSSION

In Experiments 1 and 2 of the present study, pigeons were trained on a modified conditional discrimination procedure in which samples were presented on each of the two side keys of a three-key stimulus panel, and the comparisons were presented on the center key and the remaining side key after the sample had been removed. After acquiring this multiple-sample-location task to high levels of accuracy, each bird was then tested for its ability to match those same samples on the center key to the comparisons on the two adjacent side keys. This modified procedure was designed to assess transfer of performance across sample locations while simultaneously eliminating the possibility that a bias to peck the closest comparison key on novel-sample trials would adversely affect the results. The performances of pigeons trained and tested in this manner showed that their comparison choices following each sample generalized from the familiar (training) locations to the novel (tested) location. Specifically, pigeons whose test trials involved contingencies consistent with the original training relation matched at accuracy levels above chance, whereas pigeons tested with contingencies inconsistent with original training matched at accuracy levels below chance. These results are precisely what would be expected if, in training, the nominal samples themselves had acquired substantial control over the choices pigeons made between the subsequently presented comparisons.

Although it is customary in the literature to describe pigeons' conditional discrimination performances in terms of such presumed sample-stimulus control, our results contrast markedly with those from previous studies that have investigated the role of stimulus location in MTS (Iversen, 1997; Iversen et al., 1986; Lionello & Urcuioli, 1998). In those studies, subjects mostly matched at chance levels of accuracy when the center-key sample stimuli from a trained conditional discrimination were subsequently presented in a new (side-key) location. Moreover, a majority of the subjects in those studies showed a bias to choose the comparison stimulus closest to the new, side-key-location sample, which raised the possibility that the bias itself may have underestimated the extent to which the nominal samples actually controlled performances.

Experiment 3 of the present study, however, showed that training with any two sample locations will yield transfer of performance to a new location. Here, pigeons learned to match with either two side-key samples, a left-key and a center-key sample, or a right-key and a center-key sample. Afterwards, their ability to match the comparison alternatives to the same samples presented at the remaining (novel) location was assessed. Once again, pigeons whose test contingencies were consistent with their training contingencies usually chose the correct comparison on the test trials more often than expected by chance, whereas those whose test contingencies were inconsistent with their training contingencies usually chose correctly less often than expected by chance. Thus, even when an opportunity to exhibit a closest key bias in testing was present (i.e., in Groups Left and Right), pigeons still transferred their learned conditional discriminations to new locations. These data demonstrate, then, that the samples (and comparisons) were, in large part, functionally equivalent no matter where they appeared.

This is not to say, of course, that sample location was an ineffective variable. To the contrary, the fact that test-trial performances in the consistent subgroups were, with few exceptions, less accurate than on training trials indicated that location was not rendered completely irrelevant by our multiple-location training procedures. Across all three experiments, the average drop in accuracy from the baseline to the test trials was 17%. Nevertheless, the drop in accuracy was substantially less than we observed in our previous sample-location study (Lionello & Urcuioli, 1998). Moreover, unlike our previous experiments, the pigeons in the present experiments' consistent conditions usually maintained accuracy levels well above chance on their novel-location test trials. Furthermore, if the performances of the pigeons in the inconsistent conditions were expressed as percentages of test-trial choices that coincided with their training contingencies (i.e., 100% minus observed test-trial accuracy), they, too, often maintained accuracy levels well above chance when their samples appeared in a novel location. This latter result is all the more impressive because pigeons in the inconsistent test conditions regularly experienced nonreinforcement for their test-trial choices. If anything, this should tend to create choice biases on those trials, which, in turn, should drive accuracy closer to chance.

Interestingly, in all three experiments, baseline-trial accuracy was not disrupted in groups tested with the inconsistent contingencies. Some disruption might be expected if matching were entirely independent of the locations at which samples and comparisons appeared. Perhaps repeated testing with novel-location samples taught these birds that center-key samples were functionally different than side-key samples. If so, then accuracy on baseline trials would remain high even as accuracy on the "contradictory" test trials increased, as we observed.

The strength of the transfer effects in the present study is surprising, considering that Lionello and Urcuioli (1998) were unsuccessful in their attempt to reduce control by sample location by giving pigeons experience with samples in multiple locations. In that study, one group of pigeons was trained on a hue-identity task in which the samples could appear on any of the three response keys with equal probability, whereas a second group was trained with the samples appearing only on the center key. Both groups then learned line-identity MTS with center samples only, after which transfer of line matching to a novel (side) sample location was assessed. The logic of this design was that if training with multiple sample locations can reduce the control that location has over choice, then the group with prior experience with multiple locations should match more accurately in the novel-location test than the group that lacks such experience. However, both groups performed at chance on the novel-location test trials and, moreover, learned the task at the same rate. Thus, in contrast to the present study, these data suggest that training with multiple sample locations does not produce matching performances that will generalize to new locations.

One possible explanation for the discrepancy between the present results and our earlier ones is that the pigeons in the three experiments reported here all had prior conditional discrimination experience that required them to match samples on the center key to comparisons on the side keys (i.e., the same type of performance required on the test trials in Experiments 1 and 2). By contrast, those used by Lionello and Urcuioli (1998, Experiment 3) were experimentally naive. Thus, perhaps prior center-key-sample experience per se, and not multiple-location training, produced the transfer effects observed here.

This alternative explanation can be disputed for a variety of reasons. First, in the critical test phase of Experiment 3 in Lionello and Urcuioli (1998), all pigeons had had prior experience matching with center-key samples (i.e., during the initial training phase of that experiment). Despite that history, none of the pigeons showed any evidence of transfer to novel sample locations. Second, if prior experience with samples at the tested location is important for observing transfer of matching to that location, then there should have been little, if any, evidence of transfer in Groups Left and Right in Experiment 3 of the present study. Pigeons in these two groups had no experience matching left-key or right-key samples to comparisons that appeared on the remaining two keys. Nonetheless, after multiple-location training, most of these pigeons generalized their conditional discrimination performances to the novel left- or right-key (i.e., inexperienced) location. Finally, the most compelling argument against the prior-experience explanation comes from some of our recent unpublished work (addressed to other issues), in which we have assessed transfer of matching by experimentally naive pigeons to novel locations following multiple-location training. These additional subjects were trained on MTS with left- and right-key samples and then, after reaching an accuracy of 90% correct or better for five of six successive sessions, they were given a novel-location test on the center key. Test sessions consisted of 48 baseline trials intermixed with 24 test trials in a manner similar to that of the present experiments. Stimuli were red and green hue samples and vertical and horizontal line comparisons. Baseline and test-trial data from these naive pigeons tested with contingencies consistent with their baseline (training) trials are shown in Figure 8. Clearly, their data are indistinguishable from those of the experienced birds reported here.

Lionello and Urcuioli (1998) suggested that even after multiple-location training, pigeons may learn to match compound samples to each comparison stimulus; in other words, that the functional samples still involve location (e.g., center-red, left-red, right-red, etc.). The data from the present study, however, challenge this conclusion. Here, most pigeons that learned a conditional discrimination with two sample locations generalized that performance (albeit with some decrement) to a novel, third location. Thus, it seems implausible that training pigeons with all three locations, as in Lionello and Urcuioli (1998, Experiment 3), would have generated location-specific matching performances.

An alternative account entertained by Lionello and Urcuioli (1998) for the failure of multiple-location training to produce transfer of matching to new locations with a new set of stimuli (i.e., after subsequent training with other samples and comparisons that initially appeared only in fixed locations) was that location-independent matching does not generalize to new stimuli. Although the present data cannot confirm or disconfirm this hypothesis (because no additional tasks were trained and tested), our current finding that performances usually transferred across locations within the same, trained stimulus dimensions seems more in line with that account.

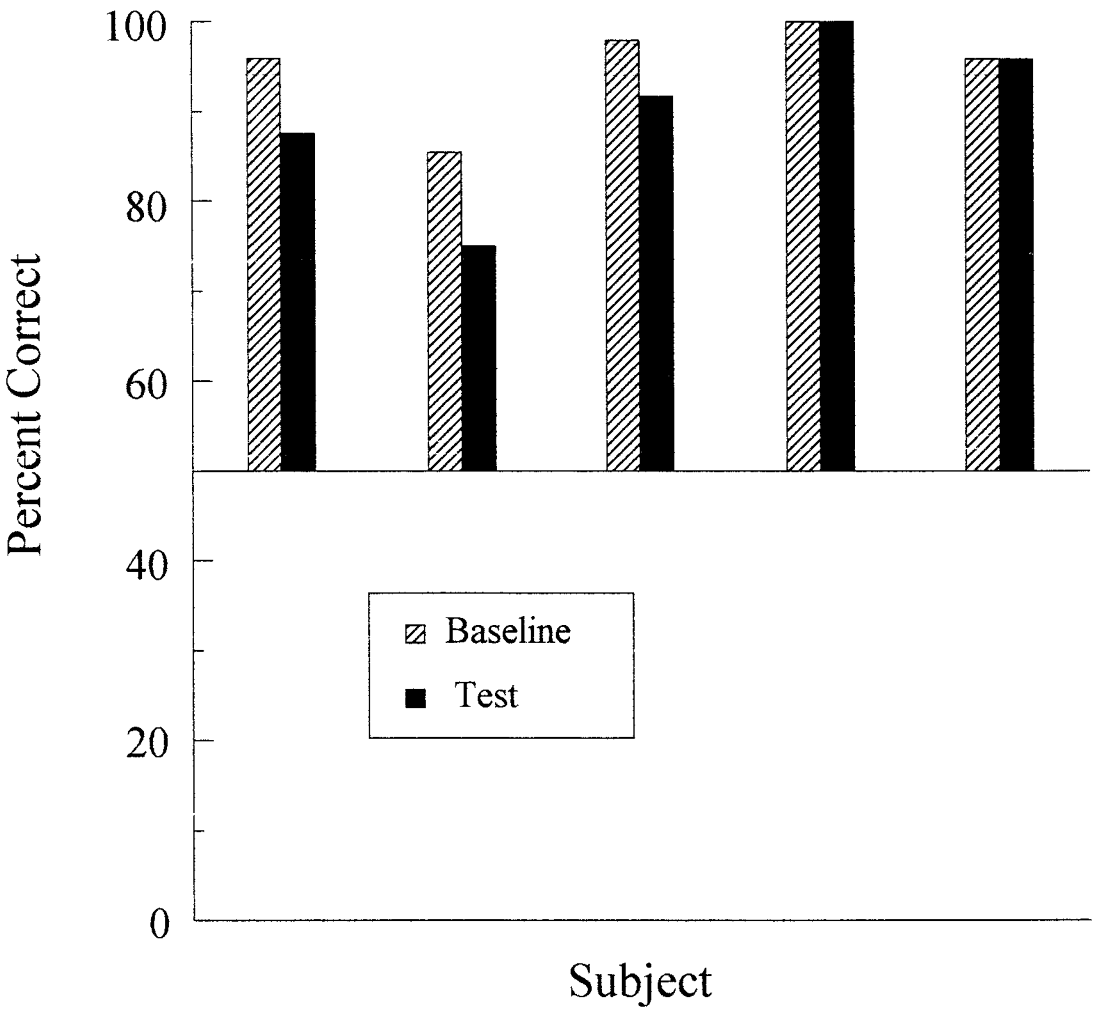

Fig. 8. Percentage correct by trial type on the first session of a moving-sample test for 5 pigeons with no prior experimental experience. Each pigeon was trained with left- and right-key samples and was given a "consistent" novel-location test with center-key samples.

Another way to test whether or not multiple-location training with one set of samples might generate location-independent matching with other samples is to train pigeons on many-to-one MTS (Urcuioli, Zentall, & DeMarse, 1995; Urcuioli, Zentall, Jackson-Smith, & Steirn, 1989). In the simplest version of this task, pigeons learn to match four samples to two comparisons: for example, to choose a vertical line comparison after either a blue or vertical sample, and a horizontal line comparison after either a yellow or a horizontal. The many-to-one procedure could be modified such that two of the samples (e.g., blue and yellow) appear in two locations during training, whereas the other two samples appear only in one location. After this task is learned to a high degree of accuracy, all four samples can then be presented in novel locations. Given the present findings, performances with the two samples trained in multiple locations should generalize to a novel location. But will this effect also occur with the samples that had appeared in only one location during training? We might reasonably expect so given that many-to-one training per se often produces an acquired equivalence among the samples occasioning the same comparison choice (Urcuioli et al., 1989, 1995). Thus, if one sample in the equivalence class supports accurate matching no matter where it appears, then perhaps others in that same class will, too, even if they have previously appeared in only one location.

In any event, the present results are noteworthy because they indicate that training with two samples increases the likelihood that pigeons will match mostly on the basis of the visual appearance of the sample stimuli. This has important implications for tests of symmetry. As mentioned earlier, one reason that performance on symmetry tests by pigeons and other animals is often at chance levels (D'Amato et al., 1985; Hogan & Zentall, 1977; Sidman et al., 1982) is that the location of the stimuli that appear in testing changes relative to training. Thus, if the location itself is part of the functional stimulus (Iversen, 1997; Iversen et al., 1986; Lionello & Urcuioli, 1998), failure to match accurately in testing is hardly surprising.

A much more discerning test for symmetry can be constructed by initially training A-B matching in such a way that the sample stimuli (A) appear in multiple (e.g., two) locations. This should reduce or eliminate control by location, thus enhancing the relative control exerted by the visual characteristics of the samples themselves. When those samples and comparisons (B) then reverse roles in the symmetry test, the likelihood that animals view the B stimuli (and the A stimuli) as identical to those in training should increase. If a symmetry test under these conditions is still unsuccessful, we can be confident that it is not due to location control, especially if additional tests show that baseline performances remain largely intact despite changes in location. On the other hand, if symmetry emerges after such training, this will indicate that prior failures were not due to behavioral limitations of the animal but, rather, to limitations generated by our procedures.

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