STIMULUS CONTROL TOPOGRAPHIES AND TESTS OF SYMMETRY IN PIGEONS

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Pigeons were tested for symmetry after A-B training under conditions designed to avoid problems that may prevent its emergence, namely the change of stimulus location in testing relative to training and the lack of requisite discrimination training. In Experiment 1, samples appeared in two locations during baseline training to minimize the impact of stimulus location. Experiments 2 and 3 included multiple-location training along with additional identity and symbolic matching training, respectively, to explicitly train all of the simultaneous and successive stimulus discriminations required for testing. Experiment 4 provided reinforcement for symmetrical matching relations with some stimulus sets (with multiple-location training) prior to symmetry testing with different sets. In all experiments, pigeons showed no evidence of symmetry despite the fact that baseline (A-B) matching transferred to novel locations. Additional tests for reflexivity (Experiment 2) yielded similar outcomes. These results indicate that the change in stimulus location is not the sole reason that pigeons do not show symmetry and increase the plausibility of arguments that symmetry and other indexes of stimulus equivalence may be beyond the capabilities of the pigeon.

Key words: symmetry, stimulus equivalence, matching to sample, stimulus location, key peck, pigeons

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When subjects are trained on symbolic matching to sample (MTS), they may learn that the samples and their reinforced comparisons "go together" (i.e., that they belong to the same class). According to Sidman and Tailby (1982), to demonstrate that training has in fact produced a class of equivalent stimuli, subjects must exhibit three distinct kinds of behavior without being explicitly trained to do so (i.e., emergent behavior). The first of these is *reflexivity,* the ability to match each stimulus to itself. The second is *transitivity,* or the ability to match A samples to C comparisons after being trained to match A to B and B to C (each letter refers to a set of stimuli). The third is *symmetry,* or the ability to match B to A after being trained to match A to B.

Evidence for equivalence class formation

after symbolic matching training is well documented in humans (Adams, Fields, & Verhave, 1993; Sidman, 1971; Sidman, Cresson, & Willson-Morris, 1974; Sidman & Tailby, 1982). Unlike the results with humans, however, data from studies with other animals have been conflicting at best. Some studies have demonstrated reflexivity in dolphins (Herman & Gordon, 1974) and chimpanzees (Oden, Thompson, & Premack, 1988), and others have found transitivity in pigeons (D'Amato, Salmon, Loukas, & Tomie, 1985; Kuno, Kitadate, & Iwamoto, 1994) and a sea lion (Schusterman & Kastak, 1993). With the exception of 2 sea lions (Kastak, Schusterman, & Kastak, 2001; Schusterman & Kastak, 1993), however, studies of symmetry indicate that nonhuman animals usually perform no better than chance on tests for this emergent relation despite a variety of training and testing procedures (D'Amato et al., 1985; Dugdale & Lowe, 2000; Hogan & Zentall, 1977; Lipkens, Kop, & Matthijs, 1988; Richards, 1988; Sidman et al., 1982).

For example, Hogan and Zentall (1977) trained two groups of pigeons to match red and green hue (A) samples to vertical and horizontal line (B) comparisons, respectively. Once baseline accuracy was high and stable, a symmetry (B-A) test was conducted in which the line stimuli served as samples and the hue stimuli served as comparisons. For

one group, choosing the comparison consistent with symmetry was reinforced (e.g., choices of red were reinforced after vertical samples and choices of green were reinforced after horizontal samples). For the remaining group, choosing the comparison inconsistent with symmetry was reinforced (e.g., choices of red were reinforced after horizontal and choices of green were reinforced after vertical). The prediction was that if symmetry had emerged from training, then test trial accuracy should be above chance for pigeons tested in the consistent condition but below chance for those tested in the inconsistent condition. Otherwise, accuracy in both conditions should be at chance. In fact, both groups matched at chance on the initial test session, and also did not differ from one another in their performances with repeated reinforced testing.

Recently, McIlvane, Serna, Dube, and Stromer (2000) proposed the notion of stimulus control topography (SCT) to explain why some subjects may not show evidence of symmetry and other components of equivalence. Stimulus control topography refers to the particular properties of a stimulus that affect performance, properties that may vary over trials or that may not coincide with those of interest to the experimenter. For instance, if a subject chooses a yellow-circle comparison on the basis of its color on some trials, its shape on other trials, and the location in which it appears on still other trials, there would be three distinct SCTs. During the course of training, control by certain topographies will tend to decrease if not consistently reinforced, whereas control by other topographies will increase if consistently reinforced. Depending on the structure of the matching task, multiple SCTs besides the one of experimental interest could be established. If so, variability in the outcomes of equivalence tests might simply reflect lack of coherence between the SCT the experimenter desires and those that predominantly control performance.

Such a lack of coherence might be one reason that pigeons do not show evidence of symmetry. For example, the A-B relations of symbolic matching typically involve the A (sample) stimuli appearing on the center key and the B (comparison) stimuli appearing on the side keys. In testing, however, the A stim-

uli are presented simultaneously on the side keys as comparisons, whereas the B stimuli are presented on the center key as samples. If pigeons learn to match the nominally defined samples (A) to the nominally defined comparisons (B), then this switch should not matter. If location itself constitutes part of the functional stimulus (e.g., if the pigeon learns in training to match "A on the center" to "B on the side"), however, then the samples and comparisons appearing in the symmetry test are functionally different from those in training. Specifically, the pigeon is confronted with "B on the center" and "A on the side" during testing in which "B on the center" may not be the same stimulus as "B on the side" and, likewise, for the A stimuli. Thus, the actual SCT and the one intended by the experimenter may not only be different but may be different in a way that precludes symmetry.

Although some researchers (e.g., Sidman et al., 1982) have considered the potential impact of stimulus location on symmetry, it is easily overlooked (e.g., D'Amato et al., 1985; Dugdale & Lowe, 2000; Hogan & Zentall, 1977). More important, the "stimulus plus location" SCT is a real consideration given recent evidence from monkeys, rats, and pigeons showing that a stimulus in one location is not the same as the identical stimulus in another location (Iversen, 1997; Iversen, Sidman, & Carrigan, 1986; Lionello & Urcuioli, 1998; Sidman, 1992).

For instance, Lionello and Urcuioli (1998) trained pigeons on identity MTS with samples always appearing on the center key. Once pigeons learned this task to high levels of accuracy, samples were then presented individually in all three possible locations (and the comparisons were presented in the remaining two). Although baseline accuracy on center-key-sample trials remained high, matching accuracy on trials in which those same samples appeared in new (i.e., side-key) locations dropped to chance (50%). Thus, what appeared to us as the same task ("match Comparison A to Sample A") was not the same task for pigeons. They had apparently learned instead to match "Comparison A on the side key to Sample A on the center key." Consequently, given "Sample A on the side," pigeons were essentially confronted with a new task (see also Sidman, 1992, for similar

effects in monkeys and Iversen, 1997, for similar results in rats).

The finding that pigeons apparently learn to match particular stimuli at particular locations to other stimuli at other locations is a perfect example of an SCT that conflicts with the one desired in training and needed for testing. The lack of transfer of baseline matching performances across locations is important because it means that reversing the roles of samples and comparisons to test for symmetry removes the effective SCT. Consequently, a failure to observe symmetry is hardly surprising. If pigeons could, instead, be trained to respond on the basis of what they see, rather than where they see it, the symmetry test results might be very different. More important, a truly "fair" test of symmetry, whatever the outcome, requires that location not be a contaminating SCT.

Some of our more recent findings (Lionello-DeNolf & Urcuioli, 2000) show that with certain training procedures, pigeons can learn to match stimuli to one another independently of their location. Specifically, pigeons explicitly trained to match comparisons to samples that can appear in more than one location transfer their matching performances to a novel location. For example, in Lionello-DeNolf and Urcuioli (Experiment 1), pigeons were trained on identity MTS with samples appearing on the left key on some trials and on the right key on other trials (the comparisons appeared on the remaining two keys). In testing, each sample appeared on the center-key location as well as on the two trained locations. Unlike the pigeons in Lionello and Urcuioli (1998), these pigeons continued to choose the comparison identical to the sample on the new-location test trials. In subsequent experiments, Lionello-DeNolf and Urcuioli showed that the two-location training procedure was also effective in reducing control by location in symbolic MTS and when any two pairs of locations (left and center, left and right, or center and right) were used in training.

These results are noteworthy because they validate a procedure for testing symmetry that will not be plagued by the confounding effect of location. If symbolic MTS training is conducted using multiple sample locations, then changing the location of the A and B stimuli during the symmetry test per se should not disrupt performances. Consequently, test trial accuracy will be a more precise reflection of whether symmetry has indeed emerged as a result of A-B training. High levels of B-A matching accuracy in testing would indicate symmetry and would confirm one source of prior unsuccessful demonstrations. Conversely, low (chance) levels of accuracy will indicate that the absence of symmetry is not solely tied to the normally disrupting effects of location change. Indeed, the training and test procedure just described can be used to verify that baseline (A-B) relations remain intact despite changing stimulus locations.

EXPERIMENT 1

Experiment 1 was designed to determine whether symmetry would emerge after A-B training in which location has been diminished as a controlling feature of the stimuli. Pigeons were trained on symbolic (A-B) MTS with samples appearing on both the left and right keys. During a subsequent symmetry test, the B samples appeared on the center key and the A comparisons appeared on the side keys. For the consistent group, choices of the comparison consistent with the symmetrical relation were reinforced. For the inconsistent group, the reinforced sample–comparison relations in testing were reversed vis-à-vis the symmetrical ones (cf. Lionello-DeNolf & Urcuioli, 2000).

Although it may seem odd to test some pigeons with sample–comparison contingencies opposite of the symmetrical baseline relations, this test condition is valuable for a number of reasons. First and most important, given that testing was conducted with reinforcement, it is imperative to know whether accuracies of the the consistent group pigeons on their initial test session (and on subsequent sessions) simply reflect new learning or emergent symmetry. If it is merely new learning, then the same should be true for the inconsistent group and, under these circumstances, accuracy of performance should not differ between groups. On the other hand, if multiple-location training does facilitate symmetry in pigeons, then the consistent group should be more accurate on its truly symmetrical test trials than the inconsistent group is on its opposite test trial rela-

tions. Ideally, first-session accuracies will be above chance in the consistent group and below chance in the inconsistent group (cf. Urcuioli & Lionello-DeNolf, 2001). Second, we wished to hedge against the possibility that even if symmetry emerged from multiple-location training, first-session performances would be at chance because the novelty of the test trials disrupted matching performances and masked a true effect. If so, symmetry would be apparent only in the faster acquisition of the B-A test relations by the consistent group than by the inconsistent group. This consideration is made even more compelling by the fact that even with human subjects, the emergence of symmetry can sometimes be delayed (Adams et al., 1993; Fields, Adams, Brown, & Verhave, 1993; Sidman et al., 1982). Thus, rate of acquisition provides another potentially useful, and perhaps relatively more sensitive, dependent measure but one that is meaningful only with a control condition that each group essentially provides for the other.

Each test session also included novel-location baseline (A-B) trials in which the original samples were presented on the center key, the comparisons were presented on the side keys, and the baseline reinforcement contingencies were in effect. These trials were an important aspect of the test procedure because the anticipated transfer of the baseline performances to novel locations would confirm that the pigeons' choices are controlled by the nominal (A and B) matching stimuli.

METHOD

Subjects

The subjects were 12 experimentally naive White Carneau retired breeder pigeons obtained from the Palmetto Pigeon Plant (Sumter, SC). The pigeons were maintained at 80% of their free-feeding weights and obtained their daily food allotment during the experimental sessions. They were housed in stainless-steel wire-mesh cages in a room on a 14:10 hr light/dark cycle. Water and health grit were freely available in the home cages. Prior to the start of the experiment, the pigeons were divided into two groups of 6.

Apparatus

The experiment was conducted in two conditioning chambers (BRS/LVE Model SEC-002) each equipped with a BRS/LVE Model PIP-016 three-key response panel. Each response key was 2.5 cm in diameter and was located 5.7 cm from the adjacent key, forming a horizontal row 7.5 cm from the top of the panel. An inline projector mounted behind each key could present the following stimuli: red and green homogeneous fields, a single white horizontal line on a black background, and a single white vertical line on a black background (BRS/LVE Pattern 696). A food hopper was accessible through an opening (5.8 cm by 5.8 cm) located 9 cm below the center key. Chamber illumination was provided by a GE 1829 houselight located at the top center of the panel. A blower fan mounted on the outside of the chamber provided ventilation and masking noise. Data were collected and experimental events were controlled by an IBM-compatible computer.

Procedure

The pigeons were initially trained to eat from the lit food hopper. Next, they were trained by the method of successive approximations to peck at a white homogeneous field on the center response key. Then, each pigeon received four 60-trial sessions in which red and green or vertical and horizontal were successively presented on one of the three response keys an equal number of times. At the beginning of each trial, a stimulus appeared on one of the keys and remained lit until it was pecked. Each peck terminated the stimulus and initiated 3-s access to the raised food hopper. A 10-s intertrial interval (ITI) separated successive trials.

In 10 subsequent preliminary training sessions, the peck requirement to each stimulus was gradually increased from 2 to 3 to 5 and then to 10 pecks. For five of these sessions, the red and green stimuli appeared on the left and right response keys, whereas for the remaining five, vertical and horizontal lines appeared individually on those keys. At the beginning of each trial, a stimulus appeared on one of the two side keys and remained lit until the response requirement was completed, at which point the stimulus went off and the food hopper was raised. Trials were separated by a 10-s ITI during which the houselight was turned off for 9 s. The houselight was turned on for the final second of the ITI.

Next, A-B matching training began: Pi-

geons learned to match red and green hue samples to vertical and horizontal line comparisons with the reinforced comparison choice following each sample counterbalanced across pigeons. Each matching trial began with a hue sample on one of the two side keys. Ten pecks to the sample turned it off and produced the two line comparisons on the remaining two response keys (i.e., the comparisons appeared on the center key and on whichever side key the sample had not been presented). A single peck to either comparison stimulus turned both off and produced reinforcement if the correct comparison was chosen or an equivalent timeout with the houselight turned off if the incorrect comparison was chosen. Following reinforcement or timeout, a 10-s ITI began, the first 9 s of which were spent in darkness. The houselight was turned on for the final second of the ITI and remained lit throughout the subsequent trial.

Each hue sample appeared equally often on the left and right keys, and the two comparisons appeared equally often on the remaining keys following each sample. The eight possible trial types were randomized in each 96-trial matching session, with the restriction that each trial type occur an equal number of times and that a given trial type not occur on more than two consecutive trials. Reinforcement duration varied between 1.8 and 6 s across sessions for each pigeon to maintain its 80% weight. Training was continued for a minimum of 10 sessions and until each pigeon reached 90% correct or better accuracy for five of six successive sessions. In addition, accuracy with both the left and right samples had to be at least 87.5% correct.

After meeting the acquisition criteria, each pigeon was given one 60-trial session in which the vertical and horizontal line stimuli were presented on the center key. Ten pecks to each line stimulus turned it off and produced 3-s reinforcement. The purpose of this session was to prepare the pigeons for the fixed-ratio 10 requirement to the line (sample) stimuli on symmetry test trials. Pigeons then received one final A-B matching session prior to testing in order to ensure high accuracy levels on the training relations.

For the symmetry test, vertical and horizontal samples appeared on the center key and red and green comparisons appeared on the adjacent side keys. For pigeons in the consistent group, comparison choices consistent with the symmetrical version of the training relations were reinforced. Thus, if the pigeon chose vertical after red and horizontal after green for reinforcement in training, then choosing red after a vertical sample and green after a horizontal sample was reinforced in testing. For pigeons in the inconsistent group, comparison choices opposite of those expected by symmetry were reinforced (i.e., choices of green were reinforced after the vertical sample and choices of red were reinforced after a horizontal sample). In addition to 24 symmetry trials in each test session, there were 48 baseline trials and 24 novel-sample-location test trials. On the latter trials, the baseline (A) samples appeared on the center key and the B comparisons appeared on the adjacent side keys. For both the novel-location and baseline trials, the original (A-B) reinforcement contingencies remained in effect. Note, too, that all test trials (location and symmetry) involved center-key samples and side-key comparisons.

Testing continued for 30 sessions or until each pigeon reached a criterion level of performance of 90% or better overall accuracy for five of six consecutive sessions and with at least 87.5% accuracy on all trial types.

Data Analyses

Statistical evaluation of overall effects both within and between groups was conducted using analysis of variance (ANOVA). When 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

During A-B training, the consistent group required 23 sessions on average (range, 14 to 64) to reach criterion levels of performance, whereas the inconsistent group required 14 sessions (range, 9 to 20). One pigeon in the consistent group (C1) did not meet the acquisition criteria but was advanced to the test phase after 64 sessions because its accuracy was both high and stable (its performance over the last five training sessions averaged 86% correct). Average matching accuracy on the last A-B training session prior to testing
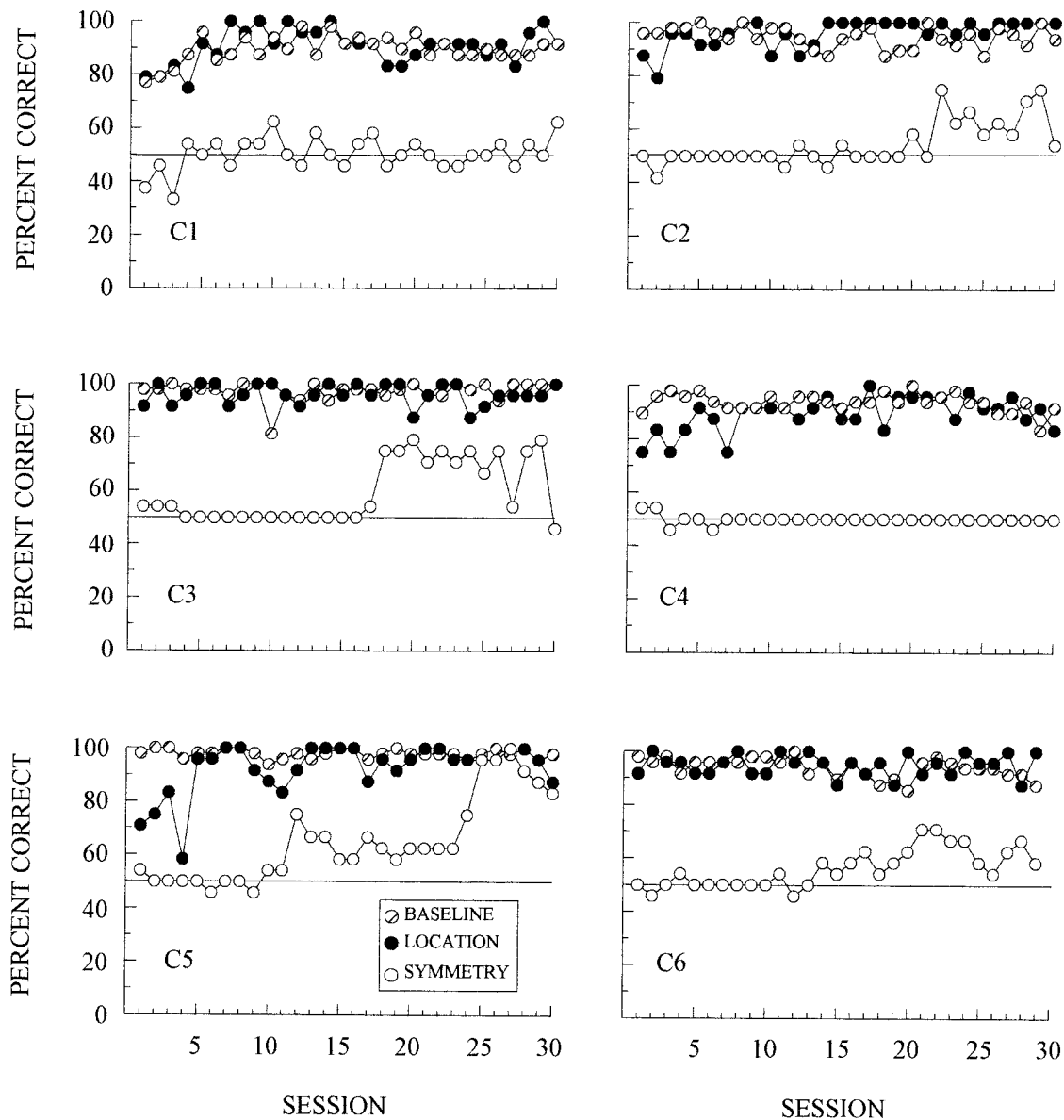
Fig. 1.   Accuracy over 30 test sessions for individual pigeons in the consistent group on all three trial types in Experiment 1. Baseline refers to the A-B training trials with samples presented on the side keys, location refers to the A-B test trials with samples presented on the center key, and symmetry refers to B-A matching trials with samples presented on the center key.

was 92% for the consistent group (range, 86% to 98%) and 95% for the inconsistent group (range, 94% to 98%).

Figures 1 and 2 show accuracy for each pigeon in the consistent and inconsistent groups, respectively, on all trial types over the 30 test sessions. Note that although the reinforcement contingencies for the inconsistent group were actually the opposite of symmetry, the "symmetry" label is used to refer to their B-A test trials as well in order to maintain continuity across the figures.

On the first test session, 5 of the 6 pigeons in the consistent group matched at or around chance (50% to 54%) on symmetry trials, as did 5 of the 6 pigeons in the inconsistent
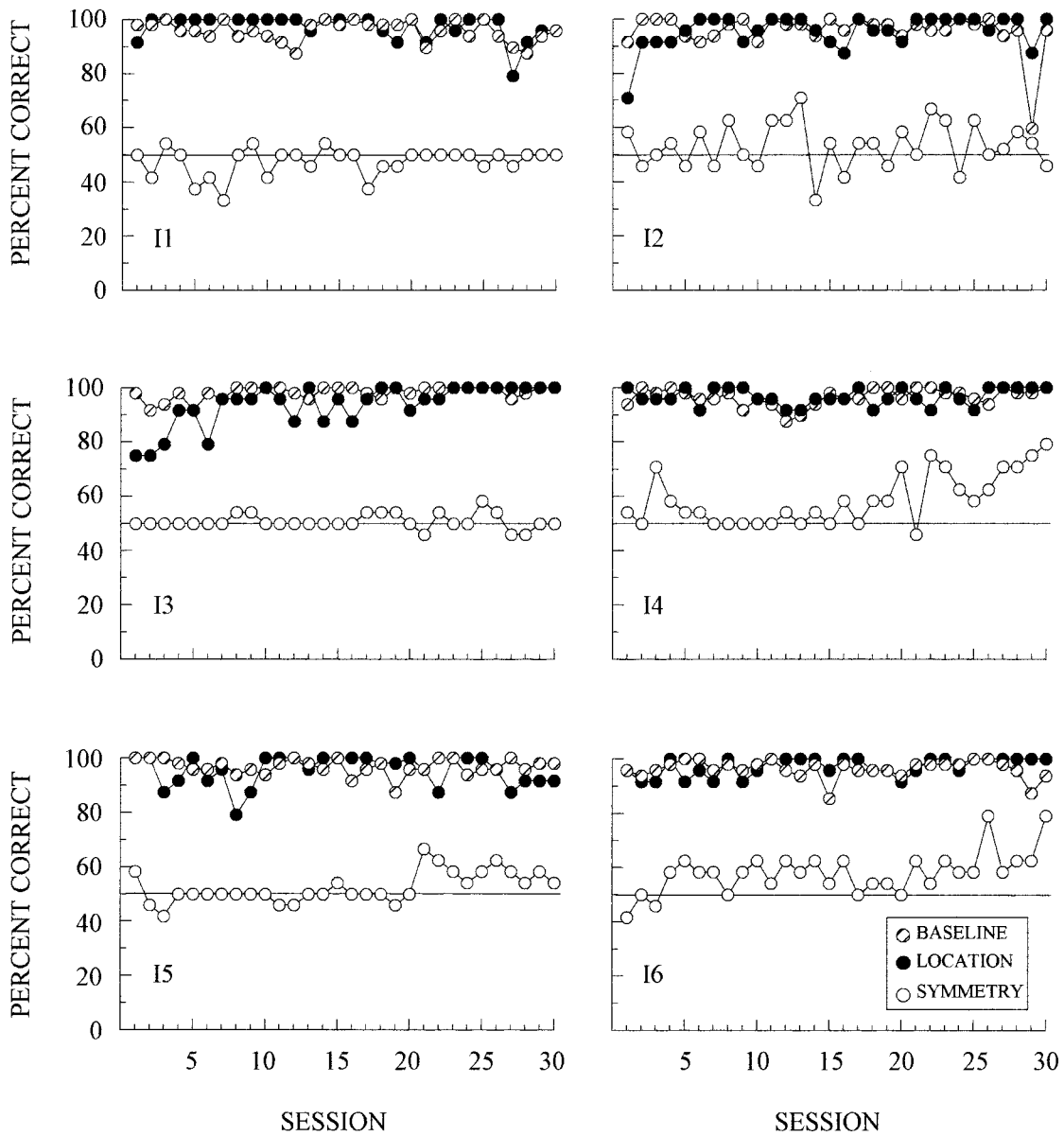
Fig. 2. Accuracy over 30 test sessions for individual pigeons in the inconsistent group on all three trial types in Experiment 1. Symmetry refers to B-A test trials in which choices inconsistent with symmetry were reinforced.

group (50% to 58%). The remaining pigeon in each group matched at 38% and 41%, respectively. Average matching accuracies were 50% and 52% for the consistent and inconsistent groups, respectively. Pigeons in both groups, however, matched well above chance on novel-location test trials (71% to 100%). All pigeons except C1 maintained high matching accuracies (90% or better) on base-

line trials in the first session as well. Post hoc contrasts from the interaction term of ANOVA on the first test session indicated that pigeons matched more accurately on baseline and location trials than on symmetry trials, $F_s(2, 20) = 49.03$ and 28.63 (the consistent group) and $F_s(2, 20) = 53.77$ and 36.42 (the inconsistent group), respectively. There were no significant differences between matching

accuracies on baseline and location trials in either group, Fs(2, 20) = 2.72 and 1.43 for the consistent and inconsistent groups, respectively.

Even with repeated testing, most of the pigeons in each group remained at chance levels of accuracy on the B-A (symmetry) test trials. Although 1 pigeon in the consistent group (C5) eventually reached 90% accuracy on its symmetry trials, there was no indication that acquisition of the B-A relations was, or would have been, any more rapid in this group than in the inconsistent group. Both groups maintained high baseline accuracy and relatively high accuracies on location trials throughout testing.

DISCUSSION

We hypothesized that previous attempts to demonstrate symmetry in nonhuman animals (e.g., Hogan & Zentall, 1977; Sidman et al., 1982) failed because the symmetry test involved functionally different stimuli than those in training as a result of the changes in stimulus location. If so, then training to establish *what* an animal sees as the functional stimulus rather than *where* it sees it should produce evidence of symmetry. Our test results, however, do not support this prediction. This experiment demonstrated that pigeons do not show symmetry after multiple-location symbolic matching training. Matching on the B-A test relations was no more accurate in the consistent group than in the inconsistent group, despite explicit procedures designed to enhance control by the nominal matching stimuli.

The results of the novel sample-location test trials verified that stimulus location had minimal effects on pigeons' matching performances (Lionello-DeNolf & Urcuioli, 2000). All pigeons matched at least at 75% correct on these trials on the first test session, with some at 90% correct or better. Moreover, by the fifth session, all pigeons were matching at the same level of accuracy on novel location trials as on baseline trials. In short, pigeons matched mostly on the basis of the perceptual aspects of the stimuli (i.e., color and line orientation) and not on where the stimuli appeared. Thus, control by stimulus location does not appear to be the sole reason that previous studies have frequently failed to find symmetry in pigeons.

EXPERIMENT 2

Although Experiment 1 showed that symmetry did not emerge despite considerable neutralization of stimulus location effects, a discrepancy between the explicitly trained discriminations and the ones required during the symmetry test may have prevented its emergence. For example, the sample stimuli (red and green) always appeared individually in training but, in testing, appeared together as comparisons. Likewise, the comparison stimuli (vertical and horizontal) always appeared together in training but appeared individually (as samples) during testing. This is a potentially serious problem because if pigeons never learn a successive discrimination between vertical and horizontal or a simultaneous discrimination between red and green, there is no guarantee that they will do so in testing (cf. Saunders & Green, 1999). One way to avoid this is to train pigeons on MTS tasks other than A-B matching to provide the requisite successive (sample) discriminations and simultaneous (comparison) discriminations needed for symmetry.

Sidman et al. (1982) familiarized their subjects (monkeys, baboons, and children) with the stimuli that would appear in the symmetry test and with these requisite discriminations by providing separate training on identity MTS with the stimuli comprising the A-B training relations. These A-A and B-B tasks also gave subjects experience with the various stimuli in all possible locations. Nonetheless, the monkeys and baboons still matched at chance on subsequent symmetry test trials. Although their findings seem definitive, location probably remained a controlling aspect of their A and B stimuli because the samples appeared only on the center key and the comparisons appeared only on the side keys (cf. Lionello & Urcuioli, 1998, Experiment 3). If so, then perhaps multiple-location training combined with additional training of the sort provided in Sidman et al. (1982) would yield symmetry.

Experiment 2, then, provided explicit training with the A stimuli from the A-B task as comparisons in one identity MTS task and the B stimuli from the A-B task as samples in another identity task, both of which involved variation in sample and comparison locations across trials. Once each multiple-location task

(A-A, B-B, and A-B) was learned, B-A matching (symmetry) was tested. We used the same pigeons from Experiment 1 because very few showed any signs of accurate B-A matching by the end of that experiment.

Prior to explicit identity training, pigeons were also tested for reflexivity with the hue stimuli from the A-B task in Experiment 1. This was included as an additional test to determine if multiple-location training would cause pigeons to treat each stimulus as the "same" no matter where it appeared (i.e., independently of its location). If so, then pigeons should match accurately on A-A reflexivity test trials from the outset. If not (e.g., if they had simply learned in Experiment 1 that the baseline sample–comparison relations were the same across locations), then the reflexivity test results should be negative.

METHOD

Subjects and Apparatus

The 12 pigeons from Experiment 1 were used, and the group designation of each remained the same. The housing conditions and apparatus were also the same.

Procedure

Immediately after completing the 30 symmetry test sessions in Experiment 1, all pigeons were tested for reflexivity. Test sessions consisted of 48 baseline (A-B) symbolic MTS trials with samples presented on the left and right keys, 24 A-B trials with samples presented on the center key, and 24 reflexivity test trials (A-A) with red and green samples presented on the center key and red and green comparisons on the side keys. Reflexivity with the line stimuli was not tested. Three pigeons from the consistent group and 3 pigeons from the inconsistent group were given an identity matching test, and the remaining pigeons in each group were given an oddity test. Note that the identity matching and oddity tests are consistent versus inconsistent, respectively, with the reflexive relations that might have emerged from A-B training. Emergent reflexivity, then, should yield above-chance accuracy in the identity matching test condition but below-chance accuracy in the oddity condition. Twenty test sessions were conducted.

Next, all pigeons were trained to criterion levels of accuracy on two multiple-location identity MTS tasks involving the red and green hues and the vertical and horizontal lines. Originally, each identity MTS session consisted of 48 hue-hue trials (24 with samples on the left and 24 with samples on the right) and 48 line-line trials (24 each with left- and right-key samples). Because most pigeons experienced difficulty learning this task, a correction procedure was added such that an incorrect choice on any trial repeated that trial until the pigeon made the correct choice. The correction procedure alone was unsuccessful in increasing overall accuracy much above chance, however, so pigeons then received alternating 96-trial sessions with just the hue or the line stimuli (i.e., just A-A or B-B matching). The correction procedure was discontinued during these sessions, but all other aspects of the matching procedure remained the same. A-A and B-B matching were alternated daily until a 90% accuracy criterion was reached. Then, hue and line matching trials were again combined into a single session. This combined A-A and B-B training continued until pigeons reached the aforementioned accuracy criteria for five of six successive sessions.

Each pigeon was then given refresher sessions on the original A-B training task from Experiment 1. These sessions were alternated daily with the combined identity MTS sessions until pigeons reached the accuracy criteria on both the A-B task and identity tasks for five of six successive sessions. Finally, pigeons were retested for symmetry in a manner identical to that of Experiment 1. Each test session included a mixture of baseline trials (A-B matching with side-key samples), novel-location trials (A-B matching with center-key samples), and symmetry test trials (B-A matching with center-key samples). Pigeons were tested until they reached 90% or better accuracy or for 20 sessions, whichever occurred first.

RESULTS

Reflexivity Test

Figure 3 presents the data for pigeons given the identity matching test, and Figure 4 presents the data for pigeons given the oddity test. On the first test session, pigeons generally matched at or near chance levels of ac-
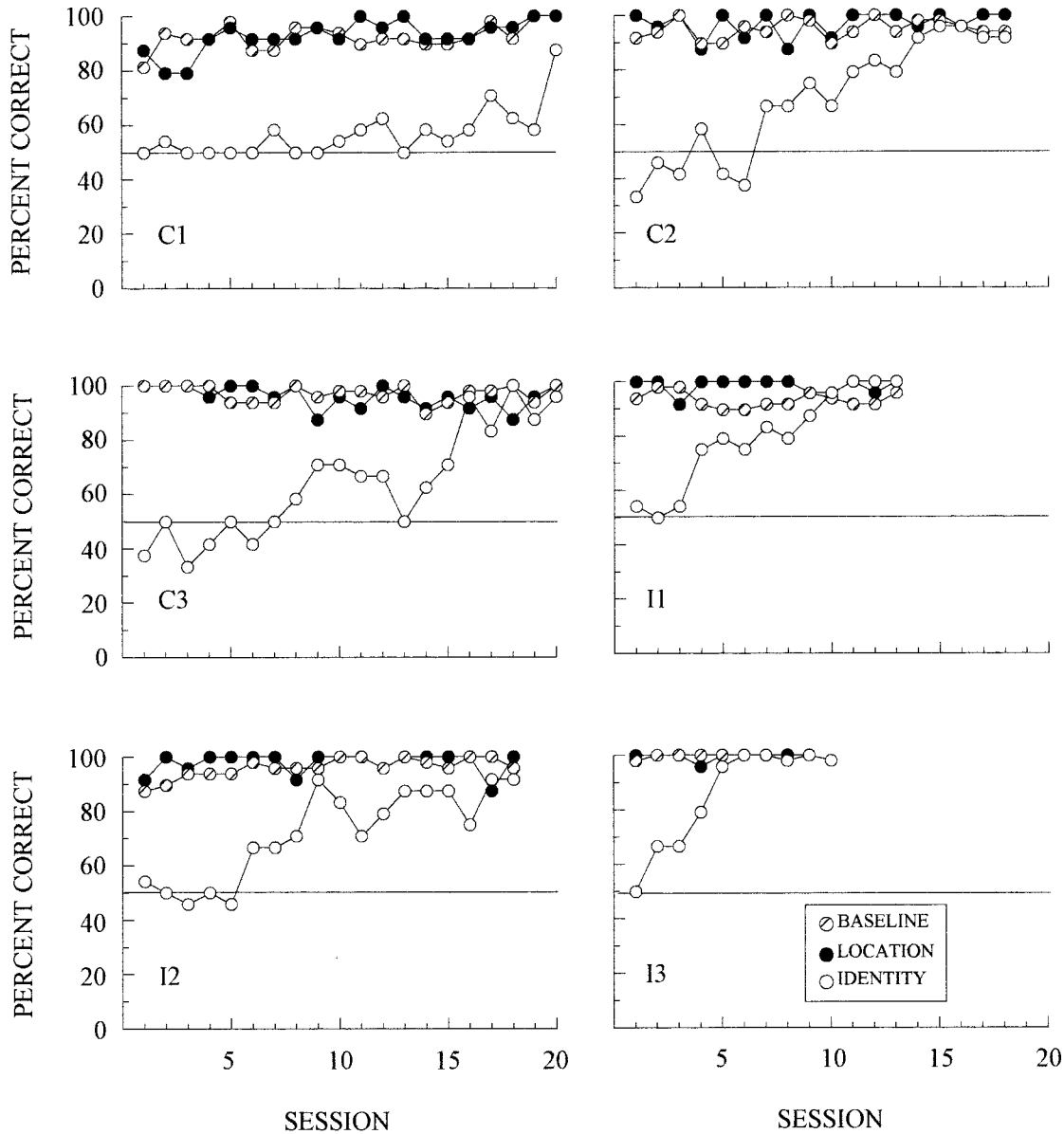
IDENTITY MATCHING TEST

Fig. 3.　Accuracy over 20 test sessions for individual pigeons on A-A identity test trials (i.e., consistent reflexivity test) in Experiment 2. Baseline and location refer to the A-B symbolic matching trials in which samples appeared on either side key or on the center key, respectively.

curacy on the A-A trials, with the exception of Pigeons C2, C3, and C5. Average A-A test trial accuracies were slightly below chance for pigeons given the identity matching test (46.5%) and slightly above chance for those given the oddity test (52%). By contrast, the

combined accuracies on baseline and novel-location trials (i.e., A-B trials with side- and center-key samples, respectively) were 92% and 96%, respectively, for pigeons tested in the identity and oddity conditions. Post hoc contrasts from the interaction term of ANO-
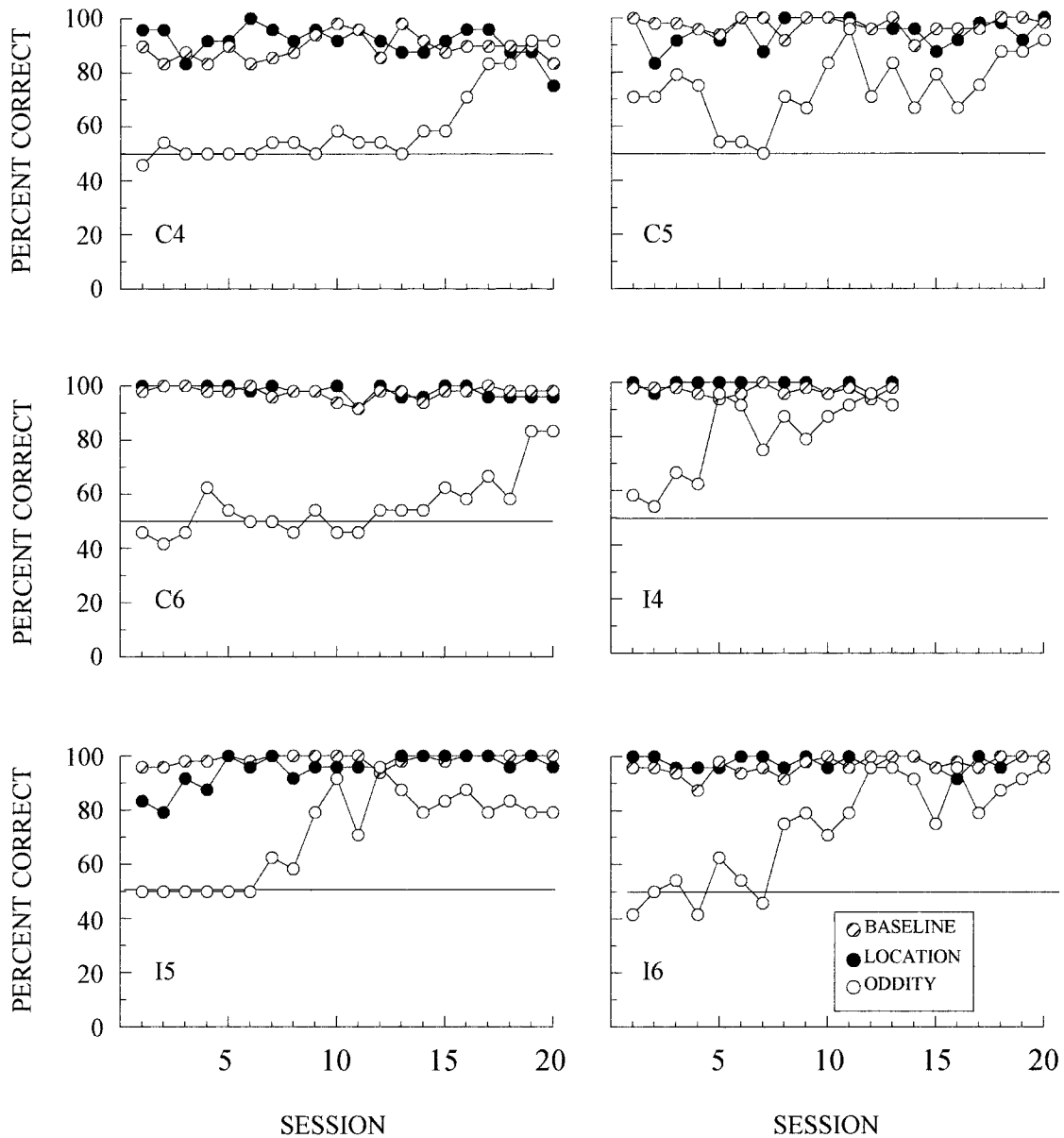
ODDITY TEST

Fig. 4. Accuracy over 20 test sessions for individual pigeons on oddity test trials (i.e., inconsistent reflexivity test) in Experiment 2.

VA showed that pigeons matched more accurately on the A-B (baseline and location) trials than on the A-A (reflexivity) trials, *F*s(2, 20) = 69.05 and 59.38, *p* < .05, for the identity and oddity conditions, respectively.

Over repeated test sessions, reflexivity test-trial accuracy tended to be variable. More-over, pigeons in the identity test condition did not acquire their A-A task any more quickly on average than those in the oddity condition: 11 sessions (range, 5 to 18) versus 13 sessions (range, 5 to 20), respectively. Accuracies on baseline and location-test trials remained high for all pigeons.

Identity Training and Symmetry Retest

Pigeons were trained for up to 59 sessions on A-A and B-B identity matching with side-key samples when the tasks were combined in a single session. Only 5 of the 12 pigeons (C3, C5, I3, I5, and I6) reached criterion levels of performance on the identity tasks and were advanced to the symmetry test. The remaining pigeons were placed on the correction procedure or were given sessions in which line and hue stimuli appeared separately. The number of sessions spent under these contingencies varied between 40 and 130. Terminal performance levels on A-A and B-B MTS, however, were similar across the two symmetry test groups: 98% and 90% for pigeons tested in the consistent and inconsistent conditions, respectively. Matching accuracy on the last A-B refresher training session preceding testing averaged 96% and 97% for the consistent and inconsistent groups, respectively.

Figures 5 and 6 depict accuracy over repeated symmetry test sessions for each pigeon in the consistent and inconsistent groups, respectively. First-session accuracy on the B-A trials was at or near chance, on average, for both groups (47% and 53%, respectively). In contrast, both groups maintained high accuracies on baseline trials (89% and 98% for the consistent and inconsistent groups, respectively). Accuracies on novel-location trials were significantly lower than those on baseline trials for the consistent group (75%), $F(1, 10) = 5.97$, but not for the inconsistent group (88%), $F(1, 10) = 3.14$, $p > .05$. Nonetheless, accuracies were well above chance for most pigeons. In addition, the inconsistent group matched more accurately on center-key and side-key baseline trials than did the consistent group, $Fs(1, 10) = 10.78$ and 5.44, respectively.

Contrary to predictions, pigeons in the consistent group did not acquire B-A matching any more quickly than those in the inconsistent group. Only 2 pigeons in each group (C5 and C6 in the consistent group and I3 and I5 in the inconsistent group) reached criterion levels of accuracy within the 20 test sessions. Matching accuracies for the remaining pigeons varied between 50% and 80% throughout testing. On the final test session, accuracy on the B-A (symmetry) test trials averaged 80% correct in both groups.

Baseline matching accuracies remained high for all pigeons except C1 throughout testing. Although accuracy on novel-location trials was initially below that on baseline trials, accuracy on these trials was similar to that on the baseline trials by the 10th session for all pigeons.

DISCUSSION

We hypothesized that one reason pigeons did not show symmetry in Experiment 1 was their inability to discriminate the vertical and line stimuli when they appeared as samples during tests. Although B-B identity training ensured this successive discrimination prior to the symmetry retest, pigeons still showed no evidence that the learned A-B relations were symmetrical. On the first test session in this experiment, most pigeons matched at or close to chance levels on symmetry test trials. Moreover, pigeons in the consistent group did not acquire B-A matching any more quickly than pigeons in the inconsistent group. The poor performance on symmetry is particularly striking given the fact that, in Experiment 1, these pigeons experienced test sessions identical to those given here.

When initially tested for reflexivity with the hue stimuli from the baseline A-B task, pigeons also matched at chance, demonstrating that multiple-location training was ineffective in producing this property of equivalence classes. In light of these reflexivity results, the failure to observe symmetry here and in Experiment 1 is not surprising. For symmetry to emerge, the pigeons must match each stimulus to itself. If this ''same'' relation does not hold between two identical stimuli (e.g., a red sample and a red comparison), there is little reason to expect it to hold between two dissimilar stimuli (Sidman, 1994). The results of the current reflexivity test demonstrate that the pigeons did not, despite multiple-location training, treat the red and green stimuli as the same whether they appeared as samples or as comparisons.

Despite no evidence for symmetry in this experiment, some pigeons acquired B-A matching, suggesting that directly training the requisite discriminations affected the pigeons' behavior (i.e., that discrimination failure had been a problem in Experiment 1).
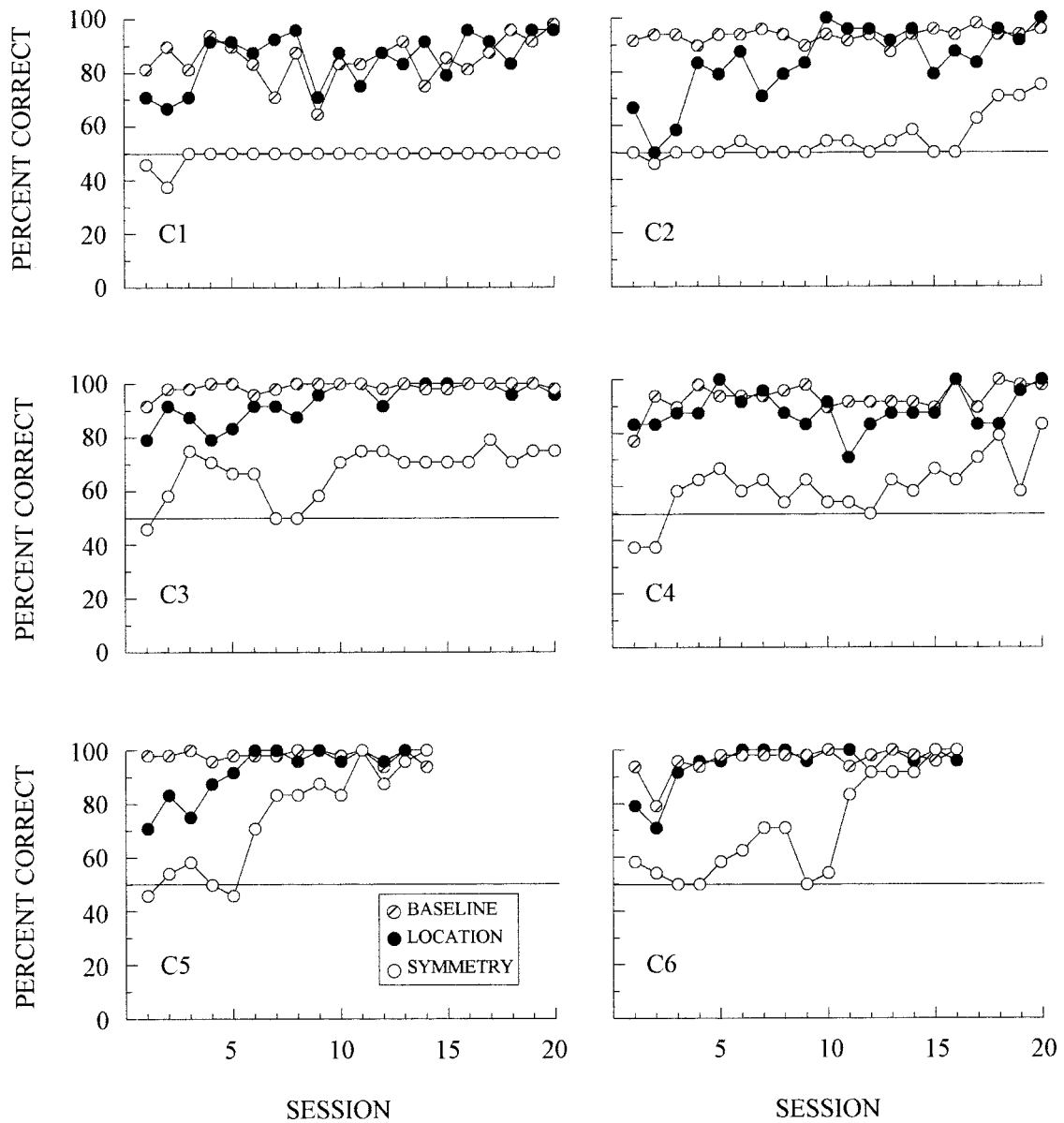
Fig. 5. Accuracy over 20 symmetry test sessions for individual pigeons in the consistent group on all three trial types in Experiment 2.

Although additional "practice" or carryover effects from Experiment 1 may have contributed too, their impact seems small given that C5, the only pigeon to acquire B-A matching in Experiment 1, initially matched at chance on the B-A test trials in this experiment and did not relearn the task any more quickly than the other pigeons.

EXPERIMENT 3

Experiment 3 systematically replicated Experiment 2 with experimentally naive pigeons and with some procedural changes to avoid problems encountered previously. For example, the pigeons in Experiment 2 experienced difficulty learning the identity MTS
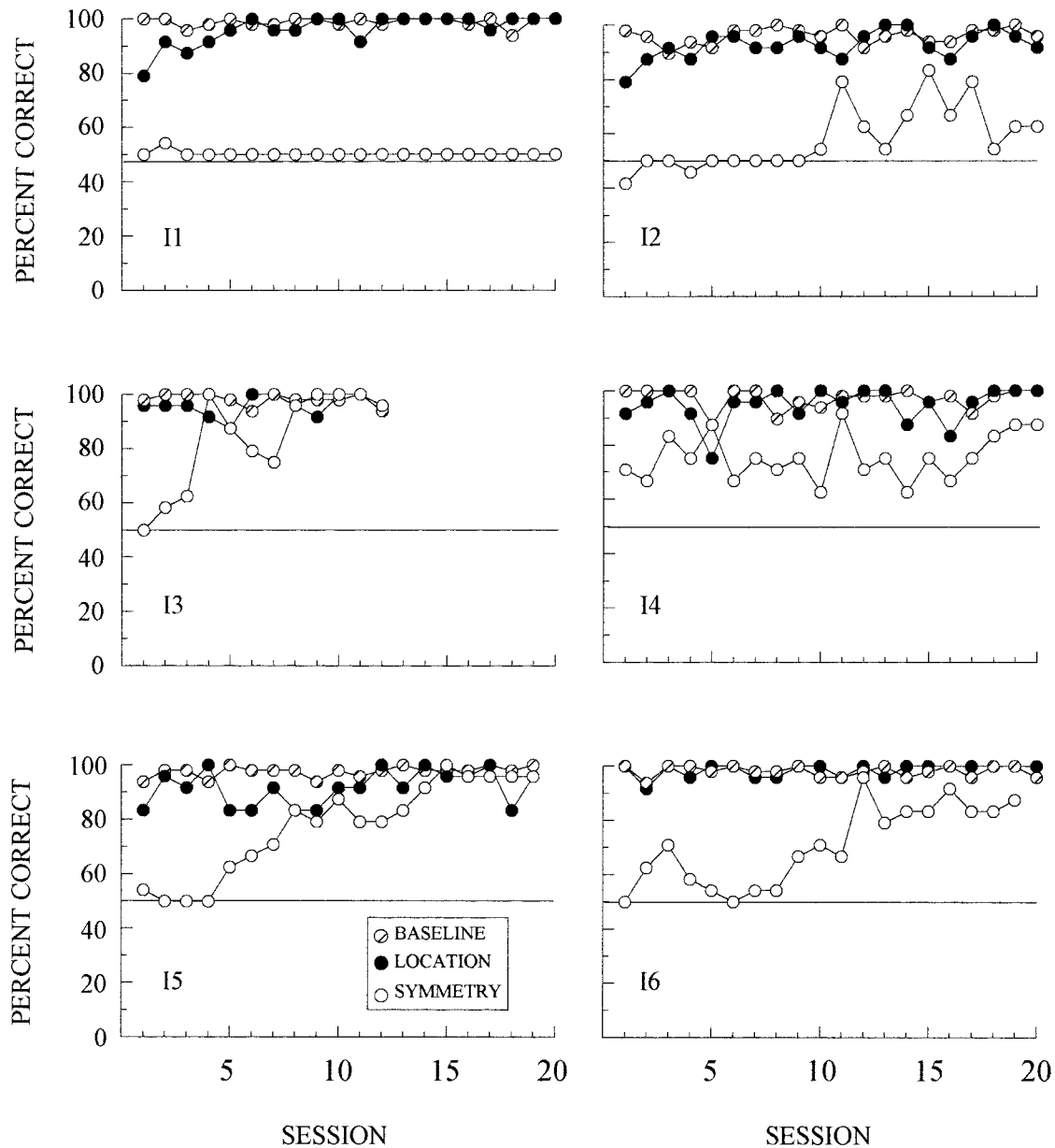
Fig. 6.   Accuracy over 20 symmetry test sessions for individual pigeons in the inconsistent group on all three trial types in Experiment 2. Symmetry refers to B-A test trials in which choices inconsistent with symmetry were reinforced.

tasks following the reflexivity test. Although the source of this difficulty is unknown, it might have affected the symmetry performances. In Experiment 3, then, pigeons were trained on two independent symbolic MTS tasks (other than the target A-B task) that accomplished the same purpose as the identity tasks in Experiment 2. For one symbolic task,

the A samples from the target (A-B) task appeared as comparisons for different sample stimuli (i.e., in C-A matching). For the other task, the B comparisons from the target (A-B) task were presented as samples for different comparison choices (i.e., in B-D matching). Thus, pigeons again learned to make both successive and simultaneous discrimi-

nations between the two hue and the two line stimuli that appeared in the symmetry test.

Second, because most pigeons in the prior experiments did not acquire B-A matching when 50% of each test session was made up of baseline (side-key sample) trials, these trials were omitted from the test sessions in this experiment. Consequently, the total amount of reinforcement was more strongly tied to performance on the symmetry test trials. This should increase the sensitivity of detecting between-group differences as a function of consistent versus inconsistent symmetrical relations.

The predictions here were the same as before. First, all pigeons were expected to transfer their baseline (A-B) matching performances to novel locations. Second, if explicit multiple-location training on all requisite discriminations yields symmetrical A-B relations, then pigeons tested with consistent B-A relations should be more accurate than those tested with inconsistent B-A relations. If symmetry does not emerge, however, the groups should not differ from one another.

METHOD

Subjects and Apparatus

Twelve experimentally naive pigeons were divided into two groups of 6. The pigeons were housed and cared for in the same manner as in Experiment 1. The apparatus was the same as in the previous experiments except that the inline projectors were modified to present a white homogeneous field, a white X on a black background, a solid white triangle on a black background, and a yellow circle stimulus (BRS/LVE Pattern 696). The yellow circle was created by placing a yellow filter over the circle stimulus.

Procedure

Following hopper training, pigeons were initially trained to peck at the white field on the center response key, after which they were trained to peck red, green, vertical, horizontal, white, X, yellow circle, and triangle stimuli using procedures similar to those of Experiment 1.

Next, all pigeons learned three symbolic matching tasks with left- and right-key samples. In Phase 1, the samples were red and green hues and the comparisons were vertical and horizontal lines (A-B matching). The symbolic relations were counterbalanced such that for half the pigeons, choices of vertical were reinforced after the red sample and choices of horizontal were reinforced after the green sample; for the remaining half, these contingencies were reversed. In Phase 2, the samples were vertical and horizontal lines and the comparisons were the white homogeneous field and the X (B-C matching), with the sample–comparison relations again counterbalanced across pigeons. In Phase 3, the samples were a triangle and a yellow circle and the comparisons were red and green hues (D-A matching), with counterbalancing as before. All other MTS details were identical to those described in Experiment 1. Pigeons were trained on each symbolic matching task for a minimum of 10 sessions and until at least 90% accuracy occurred for five of six successive sessions. In addition, accuracy with samples in each location (left and right) needed to be at least 87.5% correct. After completing Phase 3, all pigeons were given daily, rotating refresher sessions on all three tasks until criterion performance was reestablished on all three within a single block.

Next, each pigeon received novel-location tests with all three training relations to test for transfer of performances to the remaining center-key location. These test sessions were conducted separately for each matching task, and each consisted of 48 training trials (24 left-sample and 24 right-sample trials) and 48 novel-location (center-sample) trials. On novel-location test trials, all pigeons received food reinforcement for choosing the same comparison after each sample as in training (i.e., all received a consistent transfer test).

For the first three location test sessions, each set of matching relations was tested once (e.g., A-B on Session 1, B-C on Session 2, and D-A on Session 3), the order of which was counterbalanced across pigeons. After the first three sessions, each pigeon was returned to its first location test (e.g., A-B) and received reinforced training on those matching relations at all three sample locations. This continued for a minimum of 9 additional days and until each pigeon matched at or above 90% correct overall for five of six successive sessions and at or above 87.5% correct

with the samples at each location. Then, the pigeons received reinforced training with the remaining two sets of baseline matching relations (e.g., B-C and D-A) at all three locations, one set at a time. After completing this series, each pigeon received a refresher session on the A-B matching relations (i.e., red and green samples and vertical and horizontal comparisons) with samples on all three keys to ensure high baseline accuracy prior to the symmetry test.

A symmetry (B-A matching) test then followed. Each symmetry test session consisted of 48 baseline trials with red and green center-key samples followed by vertical and horizontal side-key comparisons and 48 symmetry test trials with vertical and horizontal samples on the center key followed by red and green comparisons on the left and right side keys. Thus, both the baseline (A-B) and the test (B-A) relations involved center-key samples. For the pigeons assigned to the consistent group, comparison choices consistent with symmetry were reinforced, whereas for pigeons assigned to the inconsistent group, comparison choices inconsistent with symmetry were reinforced. Pigeons were tested for a minimum of 10 sessions and until the aforementioned accuracy criteria were reached.

RESULTS

Although the number of training sessions to criterion for each set of baseline relations with side-key samples varied considerably across those relations (range, 5 to 90 sessions), matching accuracy over the last five sessions with each baseline relation was both high (92% to 95%) and similar across groups.

Figure 7 depicts matching accuracy for each group on the initial three novel-location tests that preceded the symmetry test. Note that all pigeons, regardless of group, received reinforcement for choices consistent with A-B baseline contingencies on these location tests. (In other words, "consistent" and "inconsistent" refer to the B-A matching contingencies experienced on the *subsequent* symmetry test.) Both groups matched well above chance (73% to 89%) on novel-location trials on the first session of each location test but at significantly higher levels of accuracy (82% to 95%) on side-key (baseline) trials, as indicated by separate group main effects in AN-

OVA for each location test, $Fs(1, 10) = 5.19$, 14.3, and 13.1, respectively.

During the reinforced novel-location sessions that followed the initial test session (data not shown), matching accuracies on the novel-location trials steadily increased such that by the end of testing, they were similar to those on baseline trials with all three sets of stimuli. On the A-B refresher session prior to the B-A symmetry test, the consistent and inconsistent groups chose the correct comparison on 97% and 96% of novel-location trials, respectively.

Figure 8 shows the symmetry results over all test sessions for each pigeon in the consistent group. Figure 9 shows the corresponding results for each pigeon in the inconsistent group. On the first test session, matching accuracy on the symmetry (B-A) trials averaged 52% and 56% for the consistent and inconsistent groups, respectively. Although 2 pigeons in the consistent group (CN3 and CN6) matched above chance, the remaining 4 matched at or below chance. Likewise, although 1 pigeon in the inconsistent group (IN6) matched below chance, 2 (IN3 and IN5) matched well above chance and the remaining pigeons matched at chance. Both groups maintained accurate baseline (A-B) performances: 94% and 98% for the consistent and inconsistent groups, respectively.

The inconsistent group actually reached the 90% accuracy criterion on the B-A test relations more quickly than did the consistent group, $F(9, 81) = 2.69$, the opposite of that predicted by symmetry. Four of the 5 pigeons in the inconsistent group matched at or above 90% accuracy within the first 10 sessions. In contrast, only 1 of the 6 pigeons in the consistent group reached that level during the first 10 test sessions. On average, matching accuracy by the inconsistent group on symmetry trials was at a level equal to that on the center-key-location baseline (A-B) trials within seven sessions, whereas the consistent group needed 14 sessions to achieve that same level of performance. With the exception of Pigeon CN2, baseline accuracies remained high throughout testing.

DISCUSSION

The pigeons in this experiment were trained on two symbolic MTS tasks in addition to the target A-B task to provide the suc-
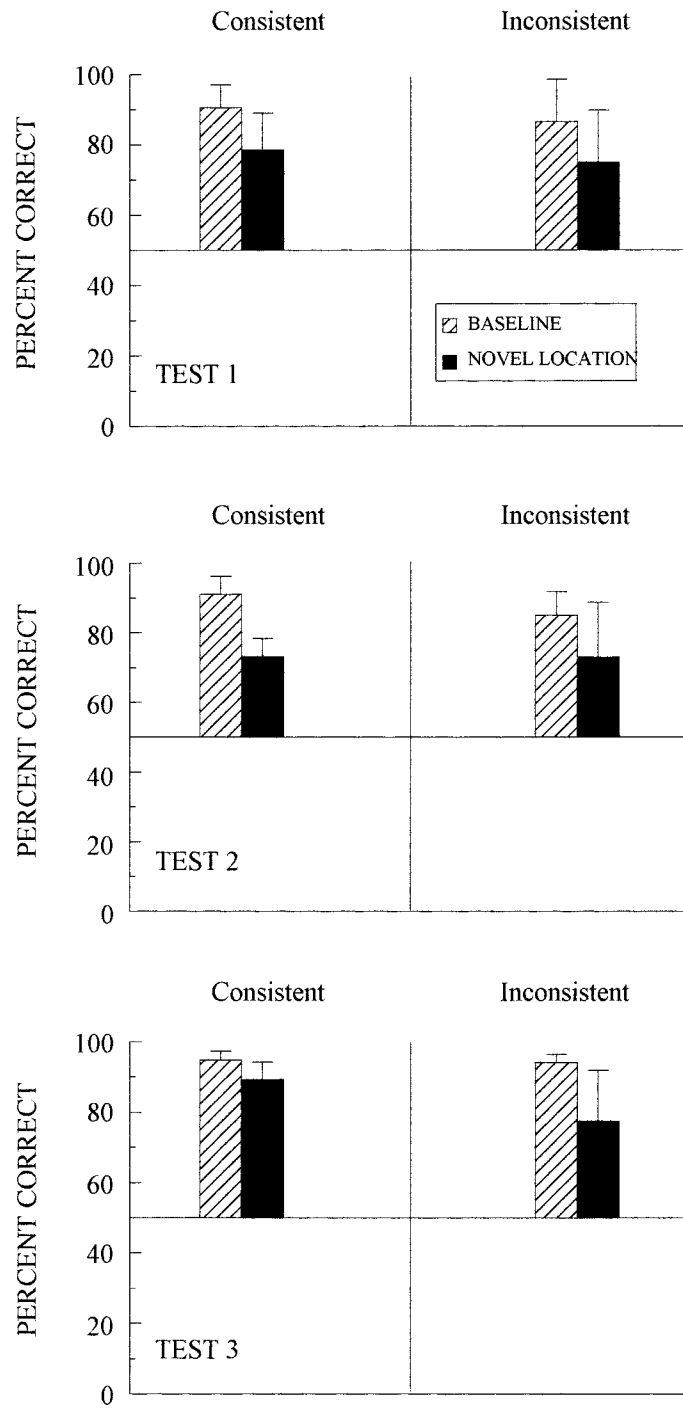
Fig. 7. Mean accuracy on the first session of each novel-location test for the consistent and inconsistent groups in Experiment 3. For both groups, choices consistent with training relations were reinforced; designations of consistent and inconsistent refer to symmetry test contingencies.
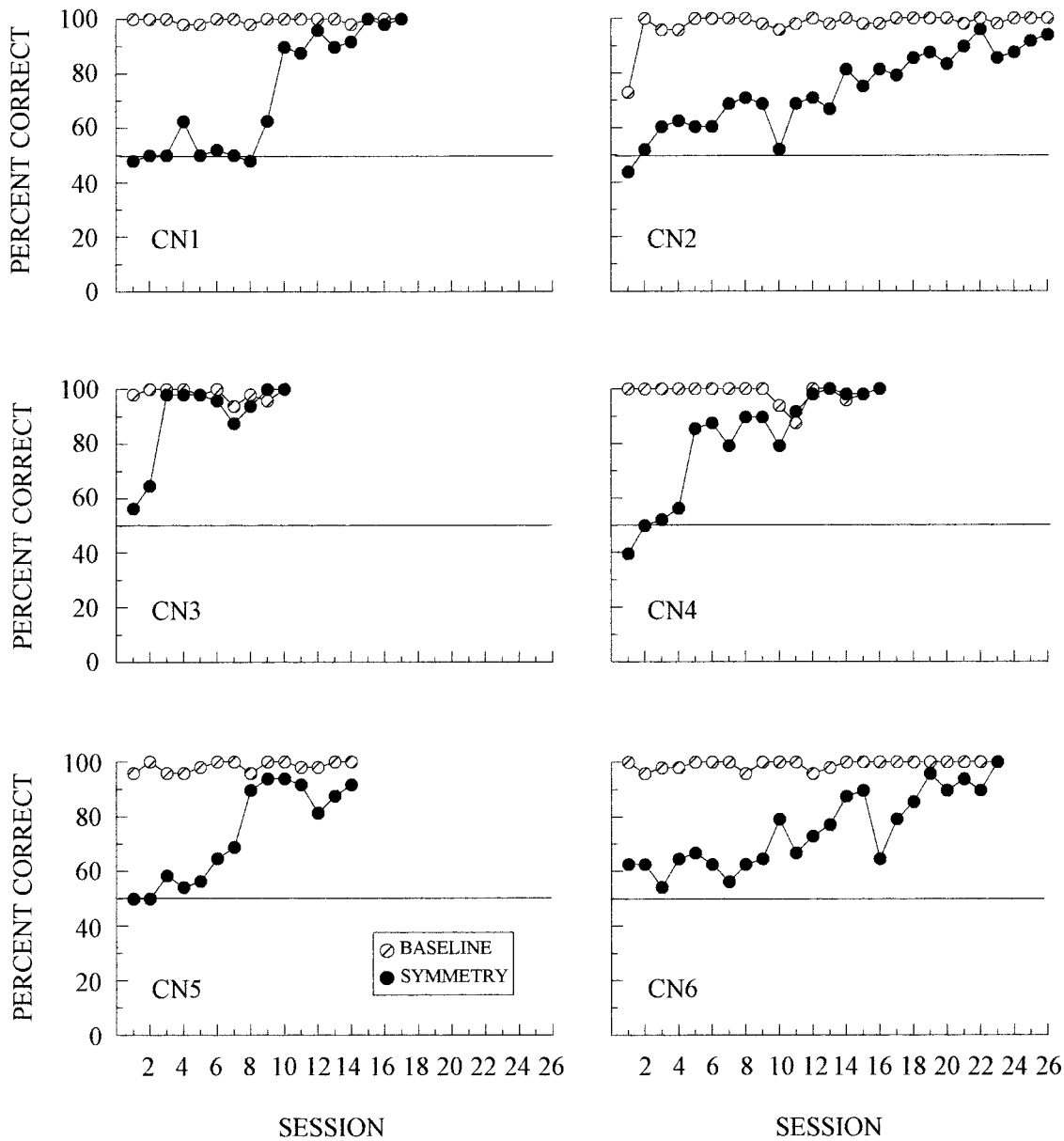
Fig. 8. Accuracy on repeated symmetry test sessions for individual pigeons in the consistent group in Experiment 3.

cessive and simultaneous discriminations between the A and B stimuli necessary for accurate performance on the symmetry test. In addition, the extra training gave the pigeons experience with each stimulus as both a sample and a comparison so that the pigeons were familiar with the stimuli in those roles prior to the symmetry test.

Despite this, most pigeons matched at or close to chance levels of accuracy on the first symmetry test. Two notable exceptions were pigeons in the inconsistent group that matched well above chance (70% to 80%). Our protocols indicate that these performances are not attributable to primary stimulus generalization. Perhaps, then, another unknown SCT enhanced their first-session accuracies, or the extensive and varied discrim-
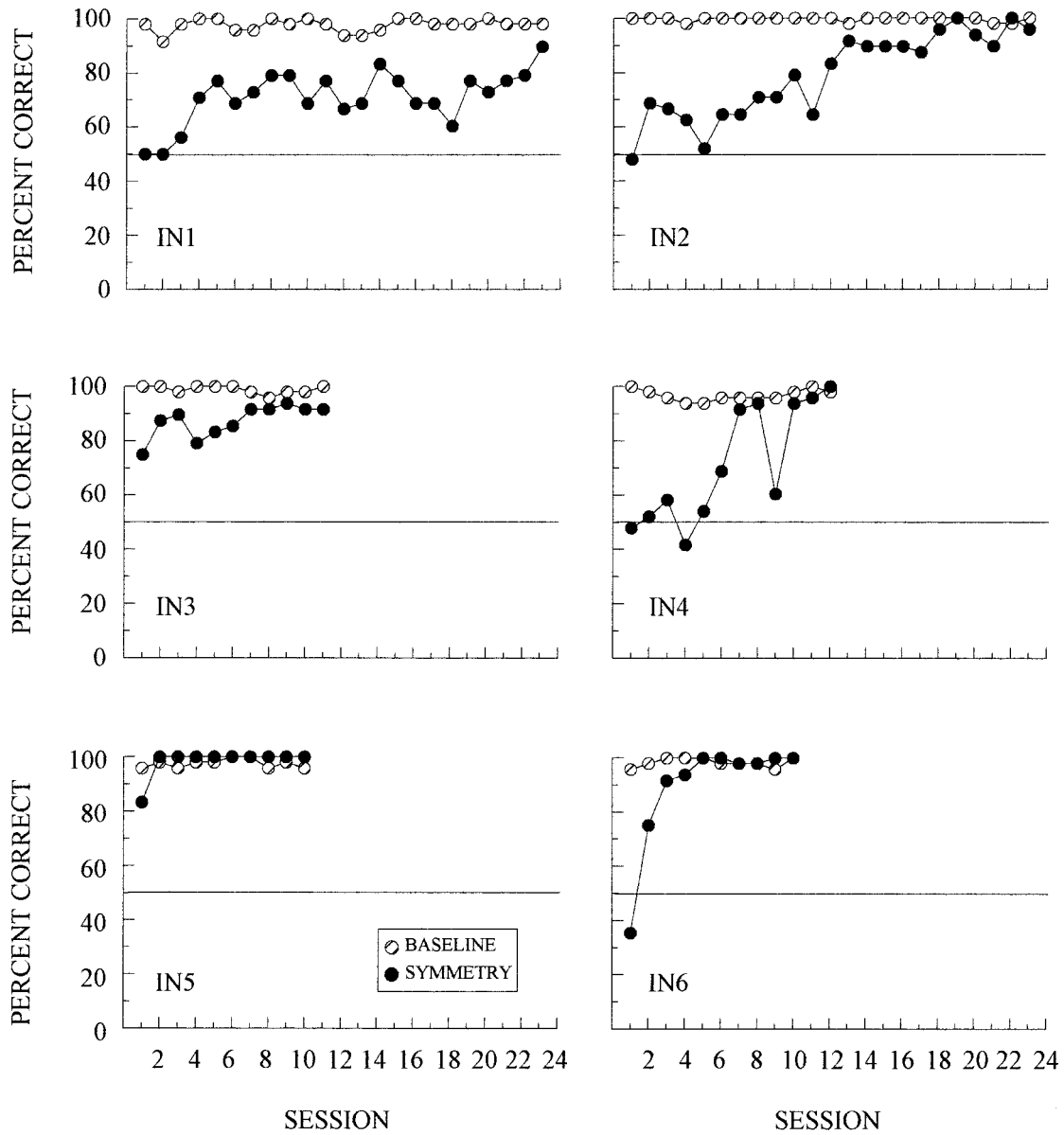
Fig. 9.   Accuracy on repeated symmetry test sessions for individual pigeons in the inconsistent group in Experiment 3. Symmetry refers to B-A test trials in which choices inconsistent with symmetry were reinforced.

ination they received prior to the symmetry test produced rapid within-session acquisition of the novel B-A relations.

The inconsistent group also acquired B-A matching more rapidly than the consistent group despite having sample-comparison test contingencies that opposed the symmetrical relations, although this difference was in large part due to IN3 and IN5, which were accurate

from the outset of testing. In any event, there was no evidence, once again, of symmetry. The predicted between-group differences (consistent > inconsistent) did not materialize even with a test session structure and a repeated testing format that were designed, quite successfully, to make the reinforcement contingencies more effective (i.e., all pigeons did acquire the B-A matching task).

As before, the pigeons in this experiment were trained with samples that appeared in two locations (the left and right keys). This was done to ensure that location was not an effective SCT. Indeed, on all three novel-location tests, pigeons matched above chance and many matched at the same level on novel-location trials as on baseline trials. Thus, location was not a major contributor to the pigeons' choices on A-B trials.

Only one other study reported in the literature (Sidman et al., 1982) ensured that subjects could make all the necessary simultaneous and successive discriminations comprising the symmetry relations. In that study, baboons and monkeys were trained on two identity MTS tasks with the A and B stimuli prior to a B-A symmetry test. The current experiment differed from that of Sidman et al. by using multiple sample-location training and by training additional symbolic relations. The results, however, were no different.

EXPERIMENT 4

Another potentially important variable for the emergence of symmetry is the subject's history of reinforced symmetrical responding (Schusterman & Kastak, 1993). Prior to the symmetry test in Experiment 3, the pigeons never experienced reinforcement for A-B and B-A matching. Schusterman and Kastak suggested (and provided evidence) that such experience may be necessary for animals to show emergent symmetry. In their study, a California sea lion was trained on multiple (30) A-B relations involving a large variety of stimuli. When later given unreinforced symmetry tests with 12 of those relations, it matched at chance. B-A matching was then explicitly trained with those 12 stimulus sets, after which symmetry tests with the remaining 18 stimulus sets were given. On these tests, the sea lion matched at greater than 90% accuracy on 14 of the 18 relations. Schusterman and Kastak attributed these positive findings to the sea lion's history of responding on symmetrical matching relations. The absence of such a training history characterizes nearly all other investigations of symmetry in animals, and in these studies, no evidence for symmetry was found (D'Amato et al., 1985; Hogan & Zentall, 1977; Lipkens et al., 1988; Sidman et al., 1982).

If a reinforced history of symmetrical responding is necessary for the emergence of new symmetrical relations in animals, then providing such a history should facilitate the effect in pigeons. Experiment 4, then, was a systematic replication of Schusterman and Kastak (1993). Pigeons from Experiment 3 that were trained to a high level of accuracy with one symmetrical matching relation were retrained on the two additional symbolic MTS tasks from that experiment and then were given symmetry tests on those relations. Although this constitutes a relatively limited history of reinforced symmetrical responding, we thought that it might nonetheless be effective, especially in conjunction with multiple-location training.

METHOD

Subjects and Apparatus

The subjects were 11 pigeons from Experiment 3. One subject (IN1) was not included because it failed to complete testing in Experiment 3. The same apparatus was used.

Procedure

The pigeons had initially been trained on three sets of symbolic matching relations and had received a symmetry test with one set in Experiment 3. Six pigeons (the consistent group) were then trained to 90% correct on the symmetrical matching relations involving the red and green and vertical and horizontal stimuli; the remaining 5 were trained to criterion on the opposing relations (the inconsistent group). Immediately following this training, the pigeons were retrained on the second set of previously learned symbolic relations (B-C) with samples appearing on all three keys. The samples were vertical and horizontal lines, and the comparisons were a white homogeneous field and an X. Retraining was continued until each pigeon reached an overall accuracy level of 90% or better for one session with at least 87.5% correct with samples in each location for one session.

All pigeons were then given a second symmetry test with white and X samples and vertical and horizontal line comparisons (i.e., C-B matching). Each test session consisted of 48 baseline (B-C) trials and 48 symmetry (C-B) trials with the samples always presented on the center key. Group designations remained

the same as in Experiment 3. Comparison choices consistent with symmetry were again reinforced for the consistent group, whereas choices the opposite of the symmetrical relations were again reinforced for the inconsistent group. Pigeons were tested for a minimum of 10 sessions and until they reached 90% correct or better accuracy on the C-B symmetry test trials for five of six successive sessions.

After completing the second symmetry test, pigeons were retrained on a third set of matching relations involving triangle and yellow circle samples and red and green comparisons (i.e., D-A matching). Upon reaching 90% accuracy, each was given its third and final symmetry (A-D) test, this time with red and green samples and triangle and yellow circle comparisons. As before, 48 symmetry test trials were intermixed with 48 baseline trials in each test session with samples always appearing on the center key. Unlike the first two tests, however, choices consistent with symmetry were reinforced for all pigeons. The rationale for this change was as follows. Pigeons in the consistent group had presumably been learning symmetrical matching relations during the two prior reinforced tests, whereas pigeons in the inconsistent group had, if anything, been learning the opposite. If these reinforced histories were effective, then the behavior of the two groups during the final symmetry test in which the reinforced relations were identical for both groups should differ. Specifically, the consistent group should initially match at accuracy levels above chance and should be more rapid in acquiring A-D matching than the inconsistent group, which should initially match at levels below chance. Pigeons were tested for a minimum of 10 sessions and until they met the aforementioned accuracy criteria.

RESULTS

Baseline Refreshers

Matching accuracies on the refresher session prior to the second symmetry test averaged 94.5% for the consistent group (range, 93% to 97%) versus 95.2% for the inconsistent group (range, 94% to 96%). On the refresher session prior to the third test, accuracies averaged 95.8% for the consistent group (range, 94% to 100%) versus 93.5%

for the inconsistent group (range, 92% to 96%).

Symmetry Test 2

Figures 10 and 11 depict the individual-subject data for the consistent and inconsistent, respectively, over the successive sessions of Symmetry Test 2. During the first test session, 4 of the 6 pigeons in the consistent group matched above chance (57% to 67%) on symmetry trials, and the remaining 2 matched below chance. In the inconsistent group, 3 of the 5 pigeons matched below chance (14% to 47%) and 2 matched above chance. Averaged across pigeons, first-session accuracy was significantly higher in the consistent group (54%) than in the inconsistent group (42%), $F(1, 9) = 6.11$.

Although a significant between-group difference also occurred on the second test session, 58% versus 47% correct, respectively, $F(1, 9) = 9.6$, it disappeared by the third test session, $F(1, 9) = 0.03$. Indeed, there was little or no evidence that the consistent group acquired the B-A task any more quickly than the inconsistent group. For example, the consistent group required an average of 6.2 and 10 sessions, respectively, to reach accuracy levels of 80% and 90% whereas the inconsistent group required 8.2 and 10.2 sessions, respectively. As before, baseline accuracies remained high throughout testing for all pigeons.

Symmetry Test 3

Figures 12 and 13 depict the individual-subject data for the consistent and inconsistent groups, respectively, over the successive sessions of Symmetry Test 3, during which all pigeons were tested with A-D relations that were truly symmetrical with the baseline D-A relations. In contrast to Test 2, average matching accuracy for each group on the symmetry trials of the first test sessions were similar: 53.4% versus 52.5% correct for the consistent and inconsistent group, respectively.

With repeated testing, all pigeons, regardless of their past histories, quickly learned the A-D matching task. Most were matching at 80% correct or better by the fourth or fifth session. The consistent group reached accuracy levels of 80% and 90% correct in 4.0 and 6.3 sessions, respectively, whereas the incon-
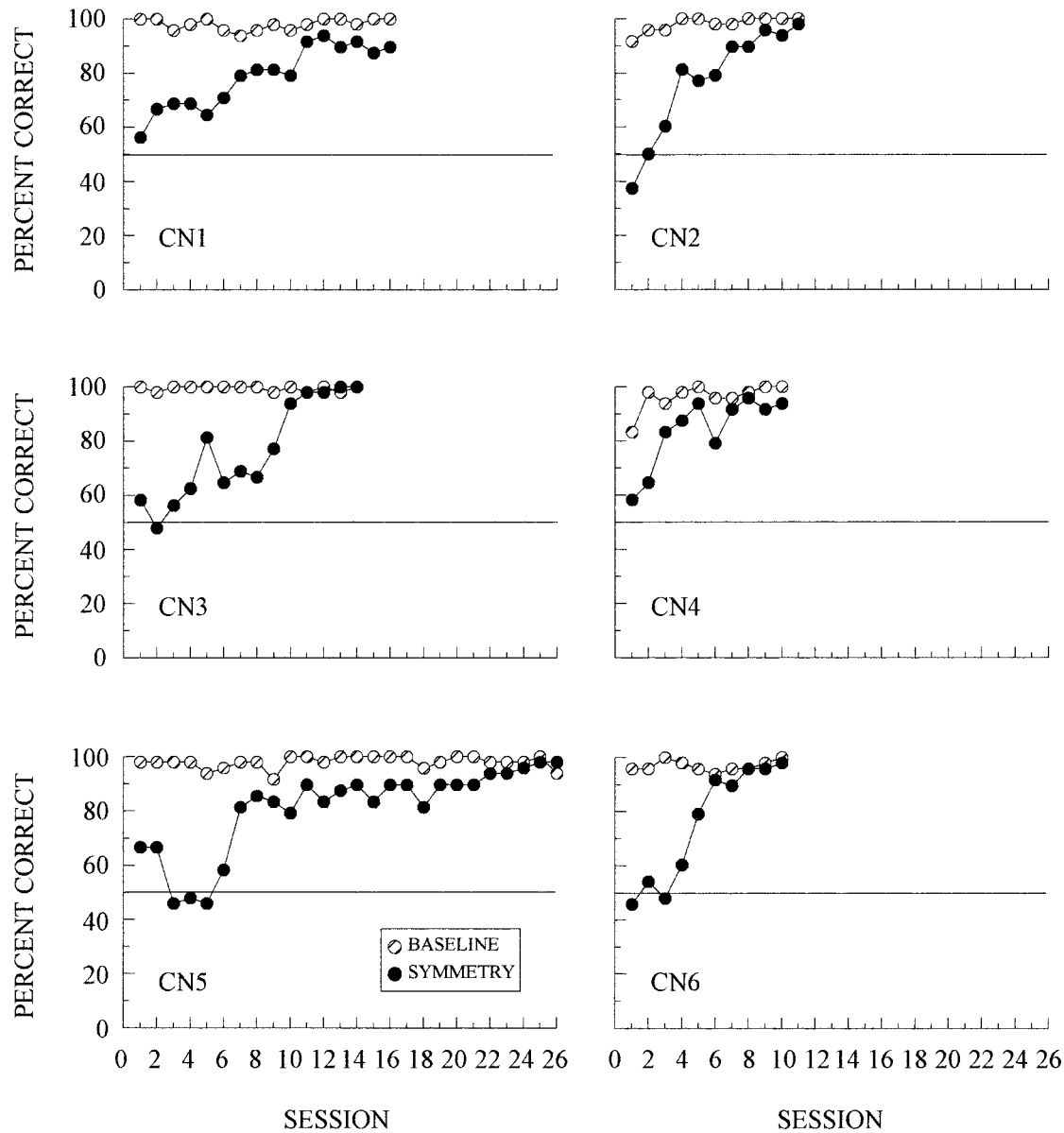
Fig. 10.   Accuracy over repeated test sessions on Symmetry Test 2 for individual pigeons in the consistent group in Experiment 4.

sistent group reached these levels in 3.6 and 4.8 sessions. Baseline accuracies again remained high throughout testing.

DISCUSSION

In this experiment, pigeons already trained to high levels of accuracy with one set of symmetrical matching relations were tested for symmetry involving a new set of stimuli. Then, performances on this second set of symmetrical relations were trained to a high level of accuracy before symmetry testing with a third set of stimuli. If such a history of reinforced symmetrical responding facilitated the emergence of symmetry, then the consistent group should have matched more accurately on Symmetry Tests 2 and 3 than the inconsistent group did.
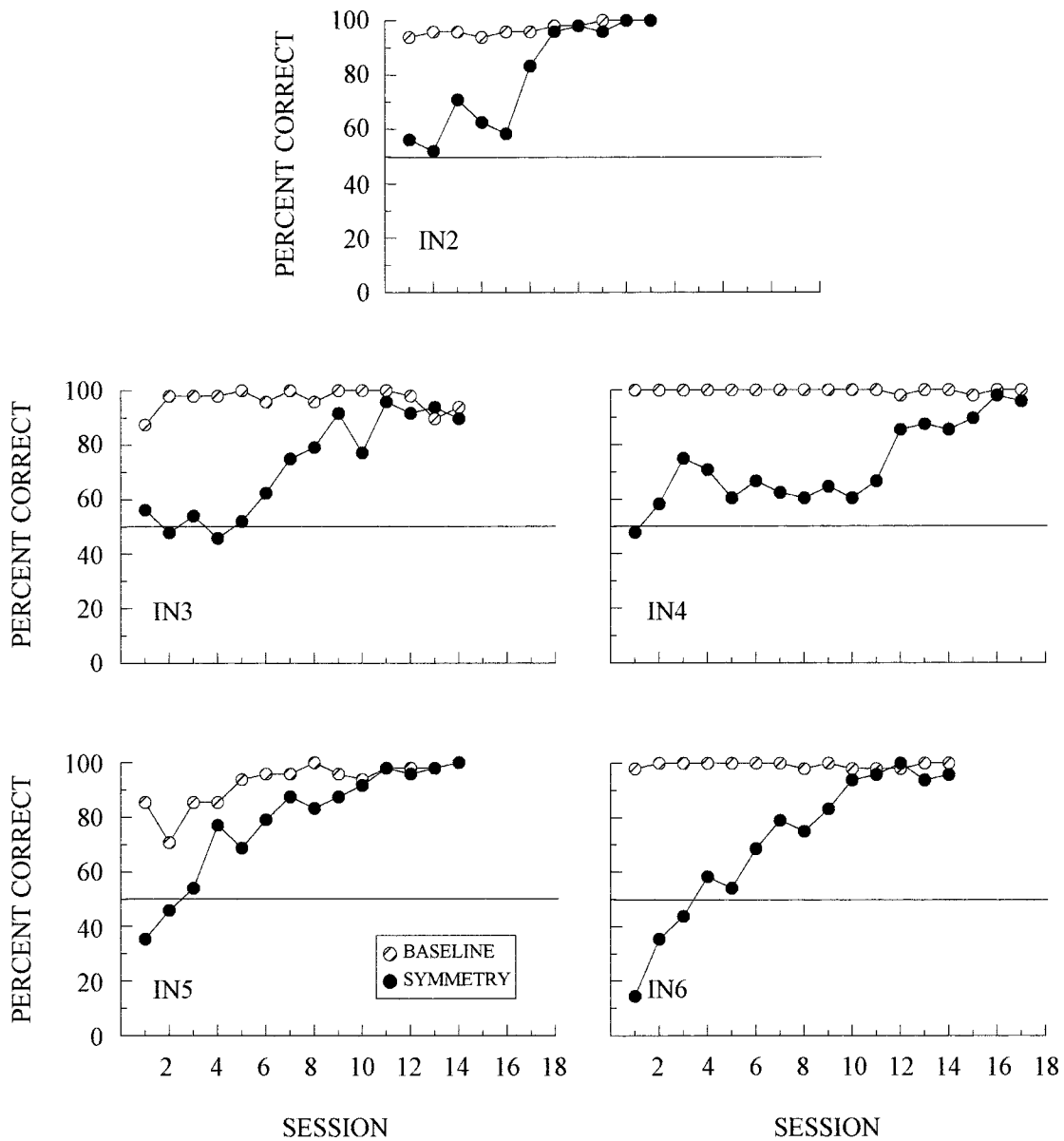
Fig. 11. Accuracy over repeated test sessions on Symmetry Test 2 for individual pigeons in the inconsistent group in Experiment 4. Symmetry refers to B-A test trials in which choices inconsistent with symmetry were reinforced.

On Symmetry Test 2, the consistent group *did* match significantly better on average than the inconsistent group. However, this difference was small and transient: the between-group differences were apparent only over the first two test sessions. In addition, the effect was largely attributable to 2 pigeons: 1 in the consistent group that matched above chance on all test sessions (CN4) and 1 in the

inconsistent group that matched well below chance over the first several sessions (IN6). Obviously, the trend within each group was tilted toward no effect.

If a history of reinforced symmetrical responding is effective in producing symmetry, stronger evidence should be found with more exposure to trained symmetrical relations, resulting in greater between-group differences
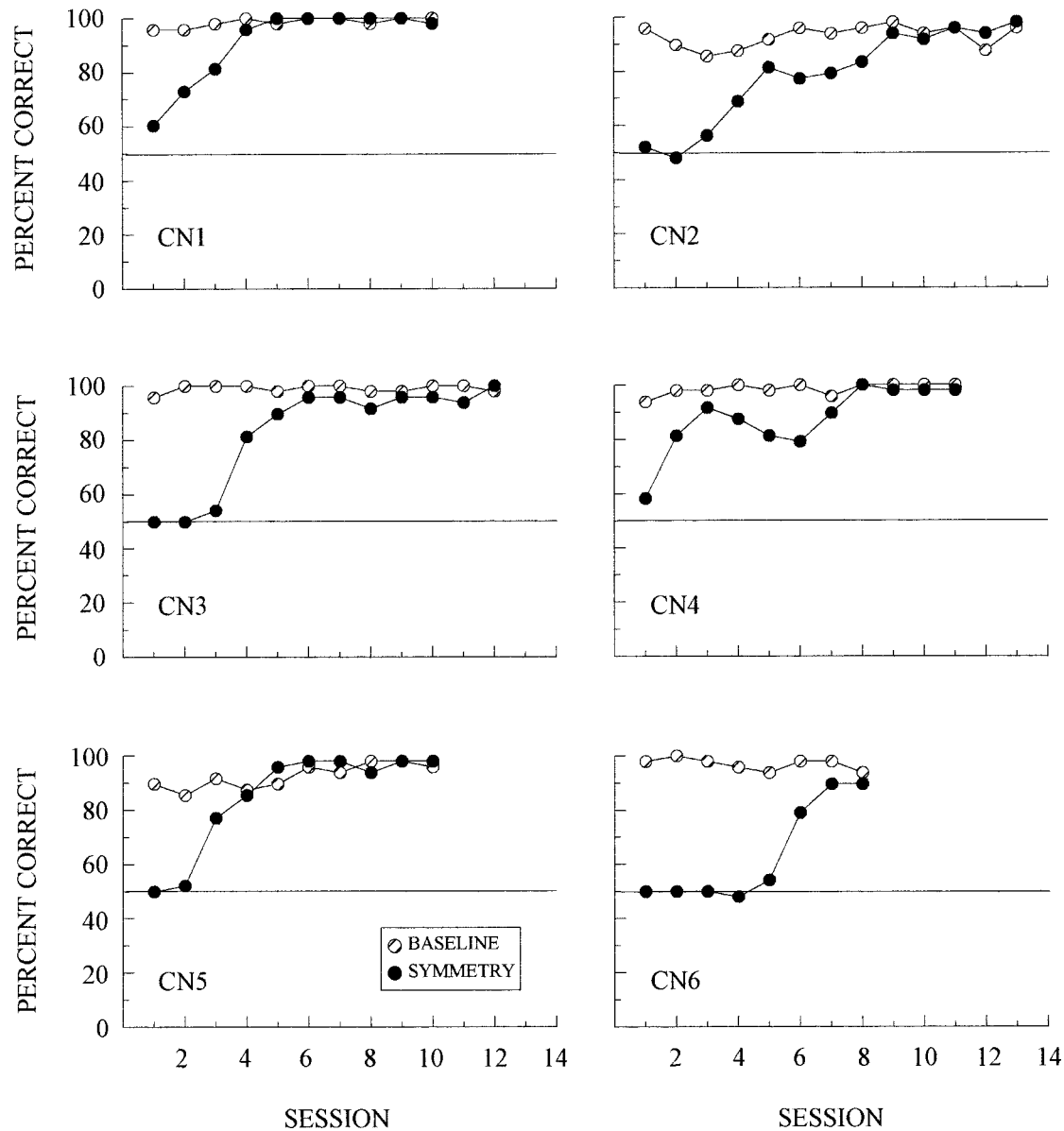
Fig. 12.   Accuracy over repeated test sessions on Symmetry Test 3 for individual pigeons in the consistent group in Experiment 4.

in Test 3 than in Test 2. There was no difference between the groups on symmetry trials on the first session of Test 3, however, and both groups matched close to chance. Although 2 pigeons in the consistent group matched above chance, they did not acquire the B-A task any more quickly than the pigeons in that group that initially matched at chance. Moreover, the pigeon that showed

the strongest positive transfer (i.e., above-chance performance) in Test 2 (CN5) matched at chance on Test 3. Apparently, then, the above-chance performance by some of the consistent pigeons (CN3 and CN5) and the below-chance performance by the inconsistent pigeon (IN6) in Test 2 reflect random variation. Had their Test 2 results truly reflected symmetry, their Test 3 results should
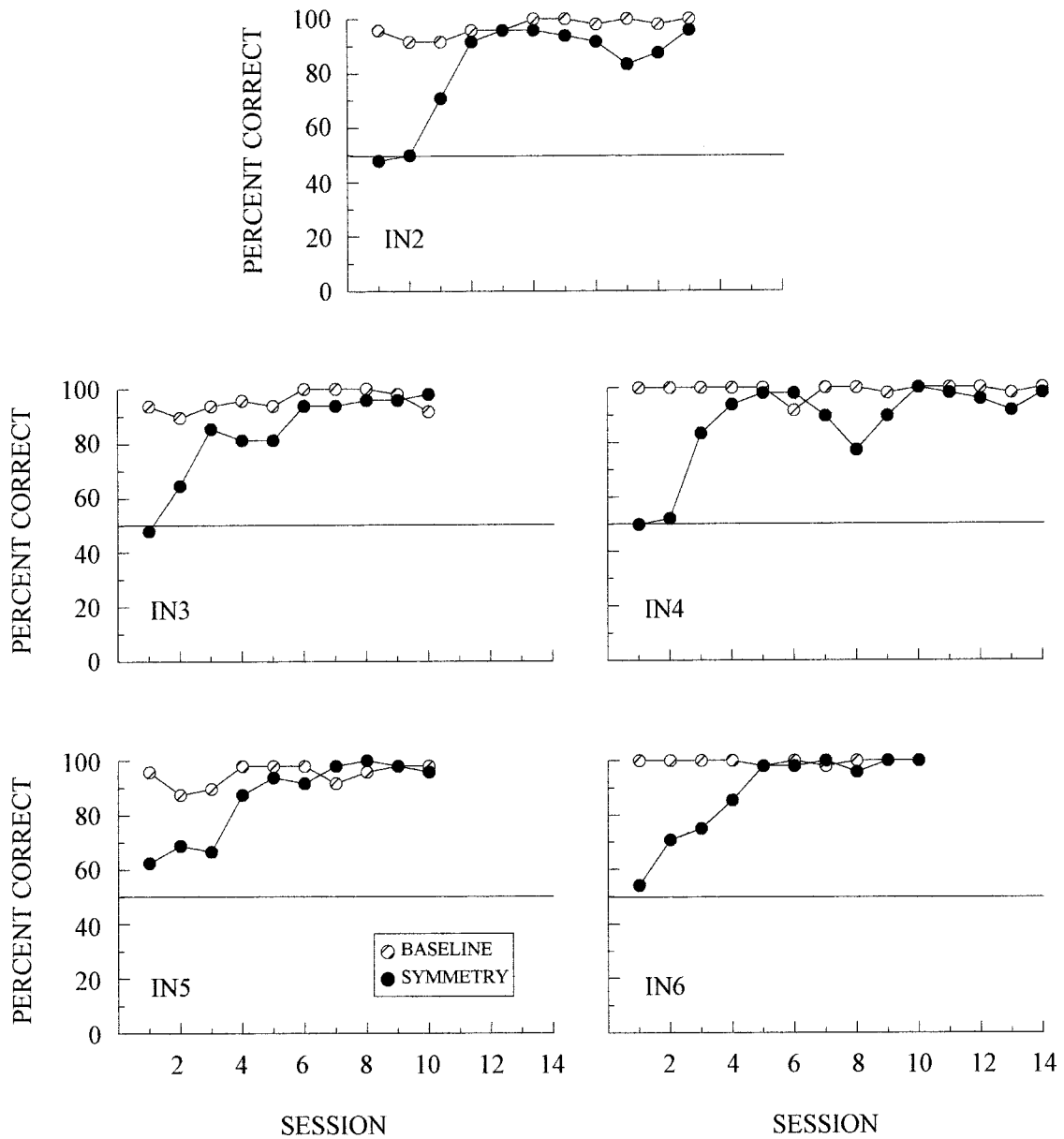
Fig. 13. Accuracy over repeated test sessions on Symmetry Test 3 for individual pigeons in the inconsistent group in Experiment 4. Symmetry refers to B-A test trials in which choices consistent with symmetry were reinforced.

have been similar or stronger, given their more extensive experiences.

The current study differed from that of Schusterman and Kastak (1993) in that our pigeons were trained on only two symmetrical relations, whereas their sea lion was trained on 12 relations prior to showing evidence of emergent symmetry. Multiple-location training, then, was not sufficient to overcome whatever constraints may arise from limited experience with reinforced symmetrical relations. Perhaps pigeons, too, need to experience a greater number of symmetrical relations before they exhibit effects of the sort observed in the sea lion.

Dugdale and Lowe (2000) attempted to replicate the results of Schusterman and Kastak (1993) using 3 language-trained chimpan-

zees with a history of explicit training on approximately 92 to 100 symmetrical relations in which they had been taught to choose a particular lexigram in the presence of an object and vice versa. The chimps were then trained on A-B matching using stimuli similar to the ones used in the current study. On a subsequent B-A symmetry test, these chimps performed poorly. Dugdale and Lowe concluded that a history of symmetrical responding is not critical for symmetry, although their chimps' history may have been inadequate because it involved natural object and lexigram stimuli that were very different from those used in the symmetry test (i.e., if training and testing involved new object → lexigram relations, symmetry may have been observed).

The results of Experiment 4 are nonetheless consistent with those reported by Dugdale and Lowe (2000). A limited history of reinforced symmetrical responding (with multiple-location training) involving stimuli of the type later tested for symmetry does not yield the later emergence of symmetry in pigeons.

GENERAL DISCUSSION

The present experiments were specifically designed to reduce the known discrepancy between the SCTs that govern pigeons' symbolic matching performances (Lionello & Urcuioli, 1998; Lionello-DeNolf & Urcuioli, 2000) and that required for a valid, and potentially successful, symmetry test. In addition, they included manipulations that ensured the sample and comparison discriminations required for symmetry and that provided a history of reinforced symmetrical responding. The results were consistent but uniformly negative in their evidence for emergent matching relations.

In Experiment 1, pigeons were trained on symbolic MTS with samples appearing in multiple locations to reduce stimulus location as an SCT. Indeed, performances on the novel-location tests were highly accurate, indicating that pigeons matched primarily on the basis of the physical characteristics of the stimuli rather than on the location of those stimuli. Despite this, pigeons matched at chance levels of accuracy on symmetry test trials.

In Experiments 2 and 3, pigeons were

trained on two additional MTS tasks (either identity or symbolic) besides the target A-B task to provide experience with the A and B stimuli as both samples and comparisons and to ensure that they could successively and simultaneously discriminate between them. Even with this additional training, symmetry still did not emerge. Moreover, reflexivity tests with the hue stimuli from the A-B task in Experiment 2 produced similar results. In other words, A-B training with multiple locations did not yield performance indicative of equivalence classes even with stimuli that were physically identical to one another.

Experiment 4 attempted, unsuccessfully, to facilitate the emergence of symmetry by providing a reinforced history of symmetrical responding. Although some suggestive evidence of symmetry was found in the test immediately following the first set of reinforced symmetrical relations (i.e., the consistent group matched more accurately on average than the inconsistent group over the first two test sessions), the effect was transient and, more important, not replicable. When tested again following a second set of reinforced symmetrical relations, pigeons matched close to chance from the outset of testing and did not differ from one another as a function of whether their prior history was consistent or inconsistent with symmetry.

The results of these experiments show that when baseline training controlled for a number of potentially problematic methodological variables, the outcome was not appreciably affected. For instance, we now know for certain that location as a dominant SCT is not the sole cause for past failures to observe symmetry because pigeons in the present experiments did not show symmetry even though they matched very accurately when stimuli from the baseline (A-B) task were presented in new locations. Likewise, past failures cannot be due simply to an inability to discriminate among the test stimuli, because all the requisite discriminations were directly trained in Experiments 2 and 3. This latter point could be gleaned from Sidman et al. (1982), too, although our results make the point even stronger given our multiple-location training procedure. Finally, the lack of a reinforced history of symmetrical responding is also not solely responsible, given that such a history, albeit with a limited number of relations, was

not sufficient to produce symmetry in Experiment 4.

The results of this study bolster the claims of Hayes (1991) and Horne and Lowe (1996) that lack of language ability is a key reason for the difficulty in observing stimulus equivalence in nonhuman animals. According to Horne and Lowe, positive equivalence test outcomes are a direct result of being able to name stimuli. Without that ability, no organism will pass a test of equivalence. Hayes' relational frame theory states that although naming per se is not responsible for positive outcomes on equivalence tests, language training is. As humans learn language, reflexive, symmetrical, and transitive responses are reinforced. The general idea, then, is that language training provides an appropriate context in which equivalence can be learned. Multiple-exemplar training of the sort provided in Experiment 4 should thus be effective in generating equivalence effects in animals by providing them with a "contextual" analogue to human language training (McIlvane et al., 2000; Schusterman & Kastak, 1993). The results of Experiment 4, however, along with those reported by Dugdale and Lowe (2000), suggest otherwise, at least when small numbers of stimulus sets are used.

Another possible reason for the failure to find symmetry here is that other competing SCTs remained. For example, in all the experiments, 10 pecks were required to each sample, but only one was required to the correct comparison. In training, pigeons may have learned that "red pecked 10 times goes with vertical pecked once." If that is the case, it does not follow that "vertical pecked 10 times goes with red pecked once," as was the case in all of the symmetry tests reported here. However, the pigeons did have some experience pecking 10 times at former comparison samples prior to symmetry testing. In Experiment 1, pigeons were given a session of pretraining just prior to symmetry testing in which they were required to peck 10 times at each stimulus that would be a sample in testing. In Experiments 3 and 4, training the three symbolic relations gave pigeons experience pecking 10 times at four of the six stimuli used as samples in symmetry testing. None of these pigeons showed symmetry. Nonetheless, this issue can easily be settled by training pigeons on multiple-location MTS in which 10 pecks are required to both the sample and correct comparison.

Another competing SCT may be the temporal relation between the samples and comparisons in A-B training. For example, pigeons may learn "match A1 at Time 1 to B1 at Time 2." If so, then pigeons would not be expected to match accurately on the symmetrical relations because they necessarily involve stimuli with different temporal loci.

Reducing the potential impact of temporal control may prove to be especially difficult, however. Simultaneously presenting the sample and comparison stimuli at the start of the trial and requiring only a comparison response would minimize the problem, but, unfortunately, it would also minimize the likelihood of learning the baseline task (Eckerman, Lanson, & Cumming, 1968). Moreover, even if pigeons were to learn such a task, the procedure might introduce stimulus configuration as another SCT that would preclude symmetry, given the new configurations produced by the test trials. Finally, even under optimal circumstances, this procedure does not guarantee the elimination of temporal cues because pigeons may nonetheless learn to observe the simultaneously presented stimuli sequentially (Wright & Sands, 1981).

Alternatively, temporal control might be reduced by presenting each stimulus as both a sample and as a comparison within the same training session, thus presumably emphasizing that *when* a stimulus appears is unimportant as opposed to *what* it is. Providing experience with many reinforced symmetrical relations seems to be one way to accomplish this. The results of Experiment 4, however, indicate that merely training two sets of symmetrical matching relations is insufficient to achieve this goal.

Finally, the reinforcement procedures of matching training itself might affect what, if any, novel relations emerge (Kastak et al., 2001; Meehan, 1999; Urcuioli & DeMarse, 1997). For example, using differential outcome training, Urcuioli and DeMarse (Experiment 2) found evidence of symmetry between the comparison stimuli and their consequent reinforcers in one-to-many MTS training (in which a single sample is followed by two or more different sets of comparisons). In the symmetry test, the outcomes

(food vs. a lit food hopper only) were presented as samples and were followed by a choice between the familiar comparisons. Urcuioli and DeMarse found that pigeons were more likely to choose the comparison that had been followed by food in training if the sample were food than if it were the lit but unraised food hopper (and vice versa). Perhaps differential outcomes facilitate the formation of two distinct categories of stimuli, whereas a common outcome (as was the case here) hinders such class formation (Sidman, 1994). Unfortunately, Urcuioli and DeMarse did not also reverse the roles of the samples and comparisons to determine if differential outcome training might also have yielded symmetrical relations between those stimuli. Nevertheless, the test data they did collect at least encourage the view that symmetry may not be language dependent.

Thus, although the current set of experiments indicate little evidence of symmetry between conditional and discriminative stimuli in pigeons, they certainly do not settle the issue. The temporal placement of samples and comparisons, for instance, may well be yet another SCT that conflicts with the desired functional relations. A more extensive history of reinforced symmetrical relations might overcome this, although this is purely speculation on our part. We do know, however, given the present results, that the SCT arising from stimulus location cannot explain past failures to obtain symmetry in the three-key MTS paradigm with pigeons.

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