

ASSOCIATIVE SYMMETRY IN THE PIGEON AFTER SUCCESSIVE MATCHING-TO-SAMPLE TRAINING

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If an organism is explicitly taught an $A \rightarrow B$ association, then might it also spontaneously learn the symmetrical $B \rightarrow A$ association? Little evidence attests to such “associative symmetry” in nonhuman animals. We report for the first time a clear case of associative symmetry in the pigeon. Experiment 1 used a successive go/no go matching-to-sample procedure, which showed all of the training and testing stimuli in one location and intermixed arbitrary and identity matching trials. We found symmetrical responding that was as robust during testing ($B \rightarrow A$) as during training ($A \rightarrow B$). In Experiment 2, we trained different pigeons using only arbitrary matching trials before symmetry testing. No symmetrical responding was found. In Experiment 3, we trained other pigeons with only arbitrary matching trials and then tested for symmetry. When these pigeons, too, did not exhibit symmetrical responding, we retrained them with intermixed identity and arbitrary matching trials. Less robust symmetrical responding was obtained here than in Experiment 1. Collectively, these results suggest that identity matching may have to be learned concurrently with arbitrary matching from the outset of training for symmetry to emerge.

Key words: key peck, pigeons, symmetry, stimulus equivalence, successive matching-to-sample, go/no go reinforcement schedule

When humans are taught that $A = B$, they can spontaneously report that $B = A$ (e.g., Sidman, 1971; Sidman, Cressen, & Willson-Morris, 1974; Sidman & Tailby, 1982). In the literature on stimulus equivalence—a type of hierarchical and bidirectional relation among stimuli that allows one to substitute for another—this bidirectional association is termed *symmetry* (Sidman & Tailby, 1982). Symmetry has been difficult to observe in nonhuman animals, even when efforts have been made to enhance symmetrical behavior by using additional training methods or stimuli that may be especially suited to the particular species (e.g., Dugdale & Lowe, 2000; Dymond, Gomez-Martin, & Barnes, 1996; Hogan & Zentall, 1977; Lipkens, Kop, & Werner, 1988; Sidman et al., 1982).

Symmetry, within the context of stimulus equivalence, is usually trained ($A \rightarrow B$) and tested ($B \rightarrow A$) using a simultaneous or 0-s delayed matching-to-sample (MTS) design. In simultaneous MTS, three to four stimuli are shown on a viewing screen at the same time.

The stimulus that is displayed at the top of the screen is the “sample” and the two or three stimuli (depending on the experimenter’s preference) that are displayed across the bottom of the screen are the “comparisons.” In stimulus equivalence training, several “if-then” relations are trained. For example, if A1 is the sample and B1 and B2 are the comparisons, then the organism would be trained to choose B1, because A1 and B1 have been arbitrarily designated as part of the same class of stimuli. Similarly, if A2 is the sample and B1 and B2 are again the comparisons, then the organism would be trained to choose B2, because A2 and B2 have been arbitrarily designated as part of the same class of stimuli. To test for symmetry, B1 and B2 now become the samples on different testing trials and A1 and A2 become the comparisons on all of the testing trials. If the organism has learned a symmetrical relation based on $A \rightarrow B$ training, then it should choose the A1 comparison when B1 is the sample, and it should choose the A2 comparison when B2 is the sample.

A 0-s delayed MTS task is very similar to the simultaneous MTS task, except that the sample stimulus is shown alone for a set period of time or until a response requirement has been met and then the sample stimulus is removed. Without delay, the comparison stimuli are then shown, and the organism is

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given reinforcement for choosing the “matching” stimulus.

Schusterman and Kastak (1993) and Yamamoto and Asano (1995) have reported evidence of symmetry in a California sea lion and a chimpanzee, respectively. But, exemplar training was given in each of these studies: that is, symmetrical relations were explicitly reinforced with multiple sets of training stimuli before the animals spontaneously expressed a backward (B→A) relation (emergent symmetry) after forward training alone (A→B) with a new set of stimuli. The likelihood of obtaining symmetry without using exemplar training has been largely unsuccessful with only a few exceptions.

In one such exception, Tomonaga, Matsuzawa, Fujita, and Yamamoto (1991; Experiment 1) observed clear evidence of emergent symmetry without exemplar training in 1 chimpanzee. Tomonaga et al. trained 3 chimpanzees on a 0-s delayed MTS task, in which an initially presented sample was turned off when the concurrently presented comparison stimuli appeared. From the outset of training, Tomonaga et al. intermixed identity matching trials (e.g., A→A) with arbitrary matching trials (A→B and B→C) consisting of color and shape stimuli; in addition, they arranged for each sample stimulus to appear in more than one possible location and for the comparisons to appear in more than two locations. One of the 3 chimpanzees showed a symmetrical result during testing that was significantly above chance (75% correct); during the first day of testing, that chimpanzee’s performance was at 100% correct.

The possibility of obtaining symmetry without using exemplar training, as in Tomonaga et al. (1991; Experiment 1), might be better realized if the problems that plague the experimental design commonly used in stimulus equivalence experiments are avoided. Specifically, with either of the MTS designs used in stimulus equivalence research, in order to test for symmetry, the stimuli that were previously comparisons must become samples and vice versa. Moving the visual stimuli to new spatial locations from training to testing might produce a measurable stimulus generalization decrement, because the visual and positional attributes of the stimuli may gain joint control over behavior (e.g., Lionello & Urcuioli, 1998; Sidman, 1992;

Zentall, 1996). Indeed, in a 0-s delayed MTS task, Lionello-DeNolf and Urcuioli (2000) found that pigeons’ matching performance transfers to new locations better following multiple-location training than following single- or fixed-location training. Presenting stimuli in multiple locations might have encouraged the pigeons to attend only to the visual properties of the stimuli rather than to attend also to the spatial locations of the stimuli. Stated otherwise, training with fixed locations of the sample and comparison stimuli in simultaneous or 0-s delayed MTS may preclude observing symmetry in testing if “moving [the visual stimuli] to new locations creates functionally different stimuli” (Lionello-DeNolf & Urcuioli, 2000; p. 142).

To address the problem of stimulus location in testing for symmetry with pigeons, Lionello-DeNolf and Urcuioli (2002) gave a 0-s delayed MTS task using three response keys: left, center, and right. They randomly showed the sample stimuli on either the left or right key and the comparison stimuli on the remaining two keys. In Experiment 1, they trained pigeons on A1→B1 and A2→B2 relations using lines and hues. During testing, they presented the B samples on the center key and the A comparisons on the left and right keys. They gave half of the pigeons food reinforcement for choosing the A1 comparison when presented with a B1 sample (consistent group), and they gave the remaining pigeons reinforcement for choosing the A2 comparison when presented with a B1 sample (inconsistent group). Lionello-DeNolf and Urcuioli (2002) found that the consistent group learned the B→A association at the same rate as the inconsistent group. This result suggests that some factor other than the spatial location of the matching stimuli may need to be controlled in order for symmetry to emerge.

For example, in addition to its *spatial* location, a visual stimulus also may be associated with its *temporal* location as well. After all, training on simultaneous or 0-s delayed MTS also entails a definite temporal order on any given trial—respond first to the sample and, then, respond to the subsequently presented comparison: first A, then B. During a test for symmetry, this temporal order is reversed: first B, then A. If temporal as well as spatial attributes are part of the functional matching

stimuli, then demonstrating symmetry requires methods that can neutralize the effects of spatial *and* temporal locations.

In Experiment 2, Lionello-DeNolf and Urquioli (2002) trained identity relations ($A \rightarrow A$ and $B \rightarrow B$) plus symbolic relations ($A \rightarrow B$) in the same manner as Experiment 1, so that the pigeons could successively discriminate between the B stimuli when they appeared in testing as samples and so that the pigeons could also simultaneously discriminate between the A stimuli when they appeared in testing as comparisons. By including identity training, this design should have effectively controlled for the temporal location of the stimuli. Lionello-DeNolf and Urquioli (2002) tested the pigeons in the same manner as they had in Experiment 1, but they again found no evidence for symmetry: The consistent group did not learn the $B \rightarrow A$ relations any faster than the inconsistent group.

It is interesting to note that 1 of the chimpanzees in Tomonaga et al. (1991; Experiment 1) did exhibit symmetrical responding during testing, whereas the pigeons in Lionello-DeNolf and Urquioli (2002; Experiment 2) did not, even though both experiments used multiple locations for the sample stimuli and they both gave identity training in addition to symbolic training. Why not?

Even though Lionello-DeNolf and Urquioli (2002; Experiment 2) gave identity training and arbitrary training, the two types of training trials were never intermixed in the same session; once pigeons learned the identity relations, they then were given a refresher on the arbitrary relations. In addition, during training, they gave the samples on one of the two side keys (i.e., left or right) and the comparisons on the remaining two keys during both identity and arbitrary training. During testing for symmetry, however, the sample was only given on the center key, whereas during training the sample was given on one of the two side keys. Hence the B sample had not been seen in the center position until testing. In other words, the spatial and temporal position of B had not been controlled and this may have led to a null symmetry result.

Another possibility may rest in the definition of stimulus equivalence proposed by Sidman and Tailby (1982). In the area of symbolic logic, the concept of identity is the same as

Sidman and Tailby's definition of stimulus equivalence. In other words, the concept of identity in symbolic logic is defined as symmetric, transitive, and reflexive (Bergmann, Moor, & Nelson, 1998). It is, therefore, possible that, by receiving training on the identity relation, a nonhuman animal gains similar learning experience to what human subjects have received long before they participated in the stimulus equivalence experiment. As seen in the above studies, however, animals may require that identity and arbitrary trials be intermixed. It also would have to be shown that giving identity matching trials is sufficient to produce generalized identity matching; such training may be a necessary condition for producing symmetry, too.

Although Tomonaga et al. (1991; Experiment 1) found emergent symmetry with 1 chimpanzee, we obviously are still a very long way from having methods for producing robust symmetrical responding in nonhuman animals without providing exemplar training. Given the small number of prior experiments purporting to find emergent symmetry, it is difficult to come to any firm conclusions about the necessary and sufficient conditions for obtaining this result. In addition, given the typical correlations between the matching stimuli and where and when those stimuli appear during 0-s delayed MTS tasks, other techniques are needed to break these potentially contaminating associations. It seems that an effective technique must control for the spatial and temporal attributes of visual stimuli that might interfere with acquisition of the appropriate baseline relations necessary to demonstrate symmetrical responding.

What training procedure might be used to effectively establish such relations? One possibility is successive MTS (e.g., Konorski, 1959; Wasserman, 1976). In this task, the sample and comparison stimuli are shown in only *one* location, which completely circumvents any distinctive associations between the matching stimuli and where they appear. In successive MTS, the sample stimulus is shown first at a particular location, turned off, after which a single comparison stimulus is shown at that same location. If the two successive stimuli are a "match," then reinforcement is contingent on responding to the comparison; if the two stimuli are not a match, then responding to the comparison is not reinforced. Typically,

pigeons come to respond to the comparison stimulus when reinforcement is scheduled and to refrain from responding when no reinforcement is scheduled (i.e., a go/no go procedure). Although successive MTS eliminates spatial location as a potentially contaminating cue by presenting all of the stimuli in the same location, it does not control for any differential association between those stimuli and their temporal location.

In the current set of experiments, we used the successive MTS procedure to train and test pigeons for associative symmetry. The use of this procedure allowed us to show each stimulus in only *one* spatial location. Additionally, in Experiment 1, we randomly intermixed both identity matching trials and arbitrary matching trials from the outset of training, so that each stimulus would also be seen in each of *two* temporal locations (Figure 1). Under these conditions, we found robust emergent symmetry during testing.

In Experiment 2, we omitted the intermixed identity matching trials during training: Two pigeons simply learned arbitrary matching ($A \rightarrow B$) alone in the successive MTS procedure. When later tested for the symmetrical relation ($B \rightarrow A$), neither showed signs of emergent symmetry.

In Experiment 3, we initially trained 2 pigeons on arbitrary matching alone and then tested for symmetry. As in Experiment 2, the pigeons showed no signs of emergent symmetry. We next trained the same pigeons with identity matching trials intermixed with the already-learned arbitrary matching trials. Once all of the stimulus combinations were mastered, we again tested for symmetry and found evidence for emergent symmetry in only 1 of the pigeons, but its results were not as strong as those in Experiment 1.

EXPERIMENT 1

In our first experiment, we used a successive MTS task to train and to test for symmetry. This task allowed us to show each stimulus in just *one* spatial location. Furthermore, we also included *identity* matching trials intermixed with arbitrary matching trials from the outset of training so that each stimulus would be seen in *both* temporal locations before testing for the symmetrical relation (Figure 1).

METHOD

Participants

Two feral pigeons (*Columba livia*) were studied. The pigeons were kept at 85% of their free-feeding weights on a 14:10 hr light/dark schedule with free access to water and grit. The pigeons had been trained to peck the center button of the apparatus in unrelated experiments.

Apparatus

Two custom-built operant conditioning chambers were used for training and testing (Young & Wasserman, 1997). Each chamber was constructed of plywood with brushed aluminum paneling on the inside of the chamber. Centered on the front wall of each chamber was a 7-cm by 7-cm square opening behind which was a clear glass touchscreen (Accutouch 002744-FTM-KI, Elographics, Oak Ridge, TN). Pecks on the touch screen were processed by a serial controller board (E271-2200, Biographies, Oak Ridge, TN). A brushed aluminum panel was placed directly in front of the touch screen to allow the pigeons access to a portion of a video monitor (13-in AppleColor[®] High-Resolution RGB) that was located 0.9 cm behind the touch screen. A clear Plexiglas food cup was centered on the rear wall of the chamber and pellet reinforcers (45-mg Pigeon Pellets Formula C1, Research Diets, New Brunswick, NJ) were delivered via a vinyl tube into the food cup from an automatic feeder (ENV-203, Med Associates, St. Albans, VT). A houselight, mounted on the upper rear wall of the chamber, provided illumination during experimental sessions. The houselight and pellet dispenser were controlled by a digital Input/Output interface board (NB-DIO-24, National Instruments, Austin, TX). Computer programs were created with HyperCard[®] (Version 2.4).

Stimuli

The stimuli were four, full-color clip-art images (Corel Gallery for Macintosh[®])—a butterfly, a flower, a snail, and a plant (Figure 1)—that were randomly sorted into two classes of stimuli (Stimulus Class 1: A1 and B1; Stimulus Class 2: A2 and B2). Table 1 shows the counterbalancing of stimuli for both pigeons (Pigeons 35Y and 67R).

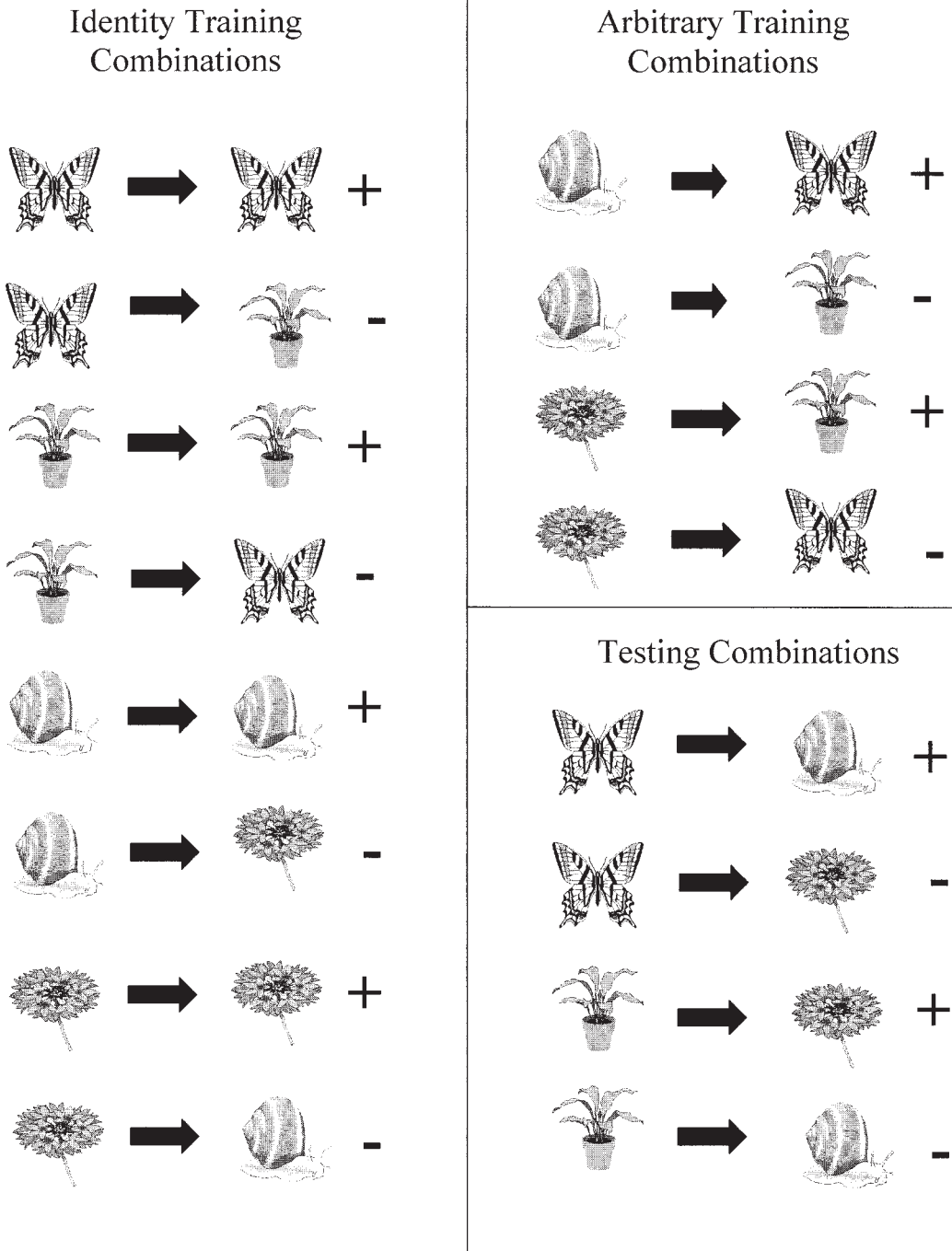


Fig. 1. Clip-art stimuli used in all three experiments. Also shown are the identity matching, arbitrary matching, and testing stimulus combinations for one of the counterbalancings.

Table 1

Stimulus assignments for all 6 pigeons in all three experiments.

Pigeon	Stimulus assignment			
	A1	B1	A2	B2
35Y	Butterfly	Snail	Plant	Flower
67R	Snail	Butterfly	Flower	Plant
27R	Snail	Butterfly	Flower	Plant
73W	Snail	Flower	Butterfly	Plant
10R	Plant	Snail	Flower	Butterfly
44R	Butterfly	Snail	Plant	Flower

Procedure

Baseline training. Each training trial began with an orienting stimulus—a white screen with a central black plus sign. After a single peck to the orienting stimulus, the pigeon was shown the first stimulus (S1) in a training combination. There were four arbitrary matching combinations as well as eight identity matching combinations in training (Figure 1). S1 was shown for a fixed interval of 10 s. When the pigeon made its first peck after 10 s, S1 was removed from the screen, there was a 3.5-s delay during which the screen was white, and then the second stimulus (S2) was shown. If the training combination was a match, then a single peck to S2 after 10 s resulted in a food reinforcer (positive baseline combination); if the training combination was not a match, then at the end of 10 s, the screen went black (negative baseline combination). Because a food reinforcer followed only the positive baseline combinations, we expected that the pigeons would peck faster to S2 of the positive baseline combinations than to S2 of the negative baseline combinations. Initially, all trials were followed by an intertrial interval of a random 5 to 10 s (ITI; see ahead for scheduling of ITIs).

Peck rate was recorded only during S2 (the comparison stimulus), from which three discrimination ratios were calculated in each session. Each discrimination ratio was calculated by adding the number of responses to the two positive baseline combinations for one type of training (e.g., arbitrary matching) and then dividing by the sum of the two positive baseline combinations and the two negative baseline combinations. One ratio was calculated for the arbitrary matching combinations and two ratios were calculated for the identity matching combinations.

If the pigeon pecked equally often to the positive and negative baseline combinations, then the discrimination ratio would be 0.50. If the pigeon pecked faster to the positive baseline combinations than to the negative baseline combinations, then the discrimination ratio would be greater than 0.50. A discrimination ratio of 1.00 meant that the pigeon pecked only at the comparisons appearing in the positive baseline combinations. During training, if the pigeon was not responding differentially to the positive and negative baseline combinations (i.e., all discrimination ratios were near 0.50), then its ITI was increased by 5 s. Because the ITI was initially a random 5 to 10 s, the subsequent increase made the ITI a random 10 to 15 s, and so on. This ITI increase followed negative baseline combinations only, and it was increased after every three completed sessions until the discrimination ratios began to increase. Initially, Pigeon 35Y would not finish its experimental sessions, so we began to increase this pigeon's ITI after 32 unfinished sessions. Its ITI was eventually increased to a random 20 to 25 s where it remained for the remainder of the experiment. It was not necessary to increase the ITI for Pigeon 67R; the ITI for this pigeon remained a random 5 to 10 s.

Each daily training session consisted of 8 blocks of 24 trials: two trials each of the 12 stimulus combinations (Figure 1). Identity trials outnumbered arbitrary matching trials 2:1. So, for example, for Pigeon 67R, arbitrary matching trials consisted of two positive combinations [Snail(A1)→Butterfly(B1) and Flower(A2)→Plant(B2)] and two negative combinations [Snail(A1)→Plant(B2) and Flower(A2)→Butterfly(B1)]. For 67R, there were also four positive identity combinations [Snail(A1)→Snail(A1), Flower(A2)→Flower(A2), Butterfly(B1)→Butterfly(B1), and Plant(B2)→Plant(B2)] and four negative identity combinations [Snail(A1)→Flower(A2), Flower(A2)→Snail(A1), Butterfly(B1)→Plant(B2), and Plant(B2)→Butterfly(B1)]. Stimulus combinations were arranged in this manner so that each stimulus would be shown in each temporal location (e.g., as S1 or S2) and so that there would be an equal number of positive and negative baseline combinations. Thus each session contained 192 trials. There were, however, several sessions during which the pigeons did not finish the complete session

for unknown reasons (see Results for number of sessions). Training sessions were conducted until all three discrimination ratios were at least 0.80 during a complete training session. A symmetry testing session was given the following day.

Symmetry Testing

Symmetry test sessions contained the four arbitrary and eight identity matching combinations used in training plus four new symmetry testing combinations, which involved the arbitrary matching combinations in reverse temporal order (Figure 1). For example, for Pigeon 67R, there were two positive symmetry combinations [Butterfly(B1)→Snail(A1) and Plant(B2)→Flower(A2)] and two negative symmetry combinations [Butterfly(B1)→Flower(A2) and Plant(B2)→Snail(A1)]. No food reinforcement was given on the symmetry testing trials. Additional testing sessions were conducted following at least one training session during which the pigeon would have to attain the 0.80 baseline performance criterion again during a complete training session in order to return to testing.¹

Symmetry testing sessions comprised 224 trials. Each session began with a warm-up block involving one trial of each of the arbitrary and identity training combinations (12 trials). The warm-up block was then followed by 7 blocks of 28 trials: two trials of each arbitrary and identity training combination (24 trials) plus one trial of each testing combination (four trials). Each symmetry testing session concluded with a block of 16 trials: one trial of each arbitrary and identity training combination (i.e., 12 trials) and one trial of each symmetry testing combination (i.e., four trials). Training and testing trials were given in this manner so that (a) a testing trial would not be seen first in any symmetry test session and (b) testing trials would be infrequent given that they never ended in reinforcement. Four discrimination ratios were calculated: the same baseline arbitrary and identity matching ratios described pre-

viously plus one symmetry test ratio. For example, for Pigeon 67R, the test ratio was calculated thusly: [Butterfly(B1)→Snail(A1) + Plant(B2)→Flower(A2)] ÷ [Butterfly(B1)→Snail(A1) + Plant(B2)→Flower(A2) + Butterfly(B1)→Flower(A2) + Plant(B2)→Snail(A1)]. Again, only responses during S2 were recorded.

RESULTS

Throughout the results sections, "positive baseline combinations" will refer to those arbitrary matching combinations of stimuli that were associated with food and "negative baseline combinations" will refer to those arbitrary matching combinations of stimuli that were not associated with food. "Positive identity combinations" will refer to those identity matching combinations that were associated with food and "negative identity combinations" will refer to those identity matching combinations that were not associated with food. "Positive symmetry combinations" are temporal inversions of the positive baseline (arbitrary) combinations and "negative symmetry combinations" are temporal inversions of the negative baseline (arbitrary) combinations. Neither the positive nor the negative symmetry combinations were associated with food (i.e., the symmetry test trials were run in extinction).

Pigeon 35Y

Symmetry Test 1 for Pigeon 35Y occurred after 136 days of training (68 incomplete and 68 complete sessions), and there were 4 days of training (0 incomplete and 4 complete sessions) between Symmetry Test 1 and Symmetry Test 2. Following training with both identity and arbitrary matching, there was good discrimination between the positive and negative identity combinations during testing for this pigeon (Table 2). There was also good discrimination between the positive and negative baseline combinations in both training and testing (Table 2). The mean response rates of Pigeon 35Y to the positive and negative baseline and symmetry combinations are depicted in Figure 2 (top left). The peck rate difference between the positive and negative symmetry combinations (0.81 pecks per second) was, if anything, a bit larger than the peck rate difference between the positive and

¹Pigeon 67R was given five testing sessions, but because Pigeon 35Y died after completing only two testing sessions, we only present the data from the first two testing sessions for all pigeons in our report. The data from 2 days of testing and from 5 days of testing were very similar for all pigeons.

Table 2

Mean response rate (pecks per second) and standard error for all stimulus combinations for all pigeons in all three experiments.

Pigeon	Stimulus combinations	Mean response rate	Standard error
Arbitrary and identity matching 35Y	Positive identity	0.99	0.07
	Negative identity	0.25	0.03
	Positive baseline	1.02	0.10
	Negative baseline	0.30	0.04
	Positive symmetry	1.08	0.16
	Negative symmetry	0.27	0.07
Arbitrary and identity matching 67Y	Positive identity	1.52	0.04
	Negative identity	0.18	0.03
	Positive baseline	1.57	0.05
	Negative baseline	0.21	0.05
	Positive symmetry	1.44	0.09
	Negative symmetry	0.40	0.10
Arbitrary training only 27R	Positive baseline	2.12	0.04
	Negative baseline	0.31	0.03
	Positive symmetry	0.89	0.07
	Negative symmetry	0.78	0.08
Arbitrary training only 73W	Positive baseline	1.02	0.03
	Negative baseline	0.55	0.04
	Positive symmetry	0.48	0.04
	Negative symmetry	0.46	0.05
Arbitrary training only 10R	Positive baseline	0.88	0.03
	Negative baseline	0.19	0.02
	Positive symmetry	0.70	0.08
	Negative symmetry	0.70	0.08
Arbitrary training only 44R	Positive baseline	1.05	0.04
	Negative baseline	0.31	0.04
	Positive symmetry	0.22	0.05
	Negative symmetry	0.17	0.04
Arbitrary and identity matching 10R	Positive identity	0.52	0.03
	Negative identity	0.10	0.02
	Positive baseline	0.54	0.03
	Negative baseline	0.06	0.02
	Positive symmetry	0.32	0.05
	Negative symmetry	0.14	0.03
Arbitrary and identity matching 44R	Positive identity	1.33	0.05
	Negative identity	0.23	0.04
	Positive baseline	1.00	0.05
	Negative baseline	0.27	0.05
	Positive symmetry	0.82	0.13
	Negative symmetry	0.77	0.11

negative baseline combinations (0.72 pecks per second); the overall difference between positive and negative combinations (both baseline and symmetry) was highly reliable (the results of inferential statistical tests for all pigeons in all experiments are shown in Table 3 and any applicable follow-up test results are shown in Table 4).²

²A Trial Type \times Positive/Negative analysis of variance was conducted for all pigeons in all experiments because a Trial Type \times Positive/Negative \times Class Number (Stimulus Class 1 or Stimulus Class 2) analysis revealed nonsignificant three-way interactions for all pigeons except Pigeon 27R (Experiment 2); that single significant three-way interaction did not reveal any salient differences from the Trial Type \times Positive/Negative interaction reported in this paper.

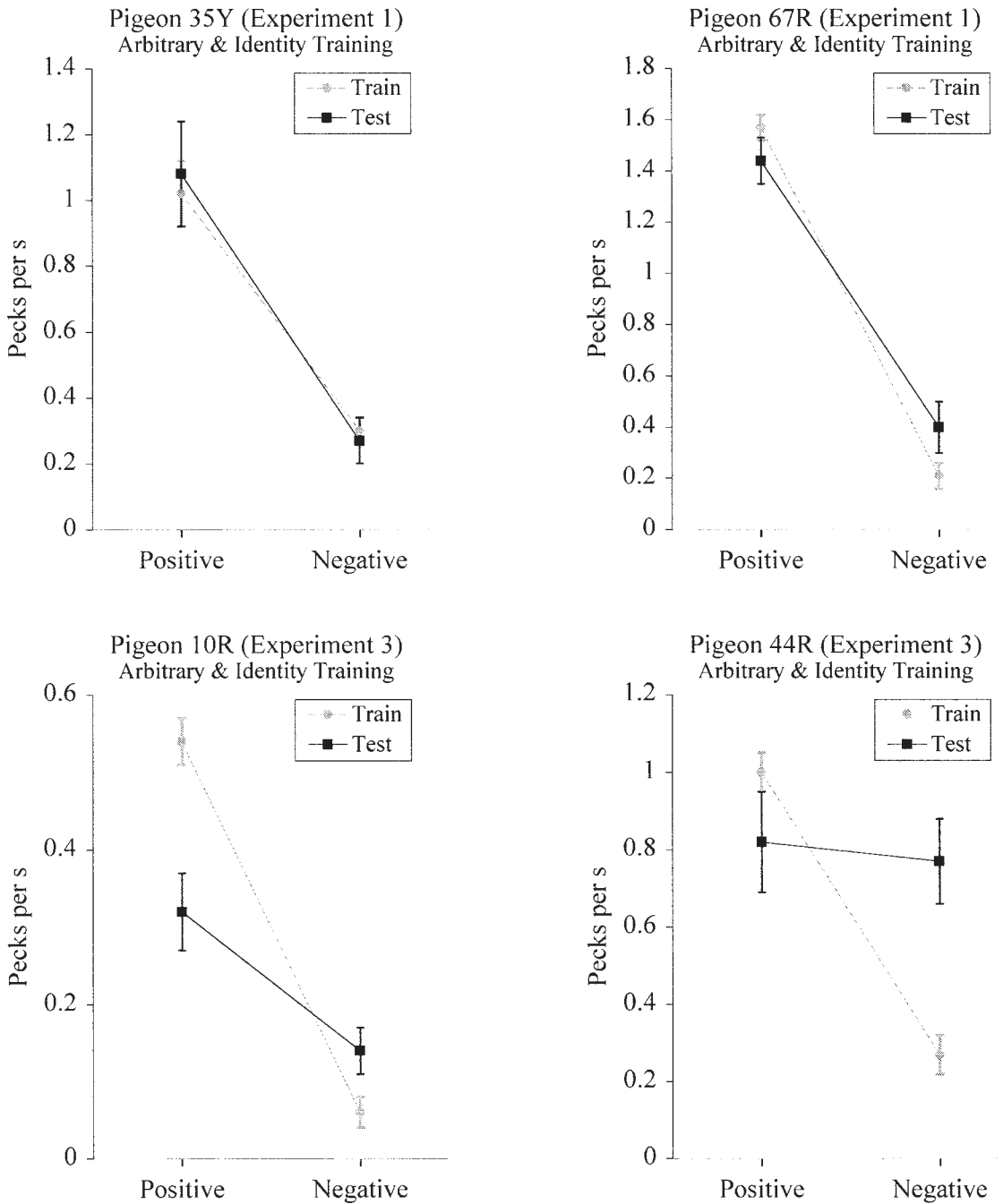


Fig. 2. Individual graphs show the mean response rates in pecks per second for the positive and negative baseline and symmetry combinations during testing for the pigeons that were trained with intermixed identity and arbitrary matching trials. Data for Pigeon 35Y (top left; Experiment 1), Pigeon 67R (top right; Experiment 1), Pigeon 10R (bottom left; Experiment 3), and Pigeon 44R (bottom right; Experiment 3) are depicted.

Table 3

Analysis of variance for Trial Type (training and testing) \times Positive/Negative (positive or negative stimulus combination).

Pigeon	Source	<i>df</i>	<i>F</i>	<i>p</i>
Arbitrary and identity matching				
35Y	Trial type (TT)	1	0.02	NS
	Positive/Negative (P/N)	1	62.93	$p < 0.001$
	TT \times P/N	1	0.19	NS
	Error	188	(0.40)	
Arbitrary and identity matching				
67R	Trial type (TT)	1	0.16	NS
	Positive/Negative (P/N)	1	283.69	$p < 0.001$
	TT \times P/N	1	4.94	$p < 0.05$
	Error	188	(0.22)	
Arbitrary matching only				
27R	Trial type (TT)	1	33.72	$p < 0.001$
	Positive/Negative (P/N)	1	219.79	$p < 0.001$
	TT \times P/N	1	173.45	$p < 0.001$
	Error	372	(0.20)	
Arbitrary matching only				
73W	Trial type (TT)	1	27.31	$p < 0.001$
	Positive/Negative (P/N)	1	15.84	$p < 0.001$
	TT \times P/N	1	14.47	$p < 0.001$
	Error	372	(0.18)	
Arbitrary and identity matching				
10R	Trial type (TT)	1	4.57	$p < 0.05$
	Positive/Negative (P/N)	1	102.41	$p < 0.001$
	TT \times P/N	1	21.24	$p < 0.001$
	Error	188	(0.05)	
Arbitrary and identity matching				
44R	Trial type (TT)	1	3.78	NS
	Positive/Negative (P/N)	1	23.28	$p < 0.001$
	TT \times P/N	1	17.99	$p < 0.001$
	Error	188	(0.28)	
Arbitrary matching only				
10R	Trial type (TT)	1	13.52	$p < 0.001$
	Positive/Negative (P/N)	1	59.36	$p < 0.001$
	TT \times P/N	1	58.43	$p < 0.001$
	Error	372	(0.10)	
Arbitrary matching only				
44R	Trial type (TT)	1	58.09	$p < 0.001$
	Positive/Negative (P/N)	1	39.05	$p < 0.001$
	TT \times P/N	1	29.88	$p < 0.001$
	Error	372	(0.19)	

Note. Values enclosed in parentheses represent mean square errors.

Pigeon 67R

Symmetry Test 1 for Pigeon 67R occurred after 65 days of training (9 incomplete and 56 complete sessions) and there were 2 days of training (0 incomplete and 2 complete sessions) between Symmetry Test 1 and Symmetry Test 2. Following training with both identity and arbitrary matching, there was good discrimination between the positive and negative identity combinations during testing for Pigeon 67R (Table 2). There was also good discrimination between the positive and negative baseline combinations in both baseline and symmetry testing (Table 2). The mean

response rates of Pigeon 67R to the positive and negative baseline and symmetry combinations are depicted in Figure 2 (top right). The mean response rate difference between the positive and negative baseline combinations (1.36 pecks per second) was larger than the mean response rate difference between the positive and negative symmetry combinations (1.04 pecks per second) (Table 3). All of the above differences were statistically reliable (Table 4).

DISCUSSION

Using a successive MTS procedure, during which identity and arbitrary matching trials

Table 4
Follow-up data for a significant Trial Type \times Positive/Negative interaction.

Pigeon	Source	<i>df</i>	<i>t</i>	<i>p</i>
Arbitrary and identity matching				
67R	P training vs. N training	2	16.51	$p < 0.001$
	P testing vs. N testing	2	8.95	$p < 0.001$
	P training vs. P testing	2	1.28	$p < 0.05$
	N training vs. N testing	2	-1.86	NS
	Error	188		
Arbitrary matching only				
27R	P training vs. N training	2	36.27	$p < 0.001$
	P testing vs. N testing	2	0.90	NS
	P training vs. P testing	2	13.42	$p < 0.001$
	N training vs. N testing	2	-5.21	$p < 0.001$
	Error	372		
Arbitrary matching only				
73W	P training vs. N training	2	10.10	$p < 0.001$
	P testing vs. N testing	2	0.10	NS
	P training vs. P testing	2	6.39	$p < 0.001$
	N training vs. N testing	2	1.01	NS
	Error	372		
Arbitrary and identity matching				
10R	P training vs. N training	2	12.76	$p < 0.001$
	P testing vs. N testing	2	3.37	$p < 0.001$
	P training vs. P testing	2	4.77	$p < 0.001$
	N training vs. N testing	2	-1.75	NS
	Error	188		
Arbitrary and identity matching				
44R	P training vs. N training	2	7.85	$p < 0.001$
	P testing vs. N testing	2	0.36	NS
	P training vs. P testing	2	1.62	NS
	N training vs. N testing	2	-4.38	$p < 0.001$
	Error	188		
Arbitrary matching only				
10R	P training vs. N training	2	19.86	$p < 0.001$
	P testing vs. N testing	2	0.04	NS
	P training vs. P testing	2	2.79	$p < 0.05$
	N training vs. N testing	2	-7.99	$p < 0.001$
	Error	372		
Arbitrary matching only				
44R	P training vs. N training	2	15.18	$p < 0.001$
	P testing vs. N testing	2	0.42	NS
	P training vs. P testing	2	9.25	$p < 0.001$
	N training vs. N testing	2	1.52	NS
	Error	372		

Note. P = positive and N = negative.

were intermixed, we found discriminative responding that was virtually identical on backward (B \rightarrow A) symmetry testing trials and on forward (A \rightarrow B) baseline trials, a clear indication that our training conditions had produced symmetry. For Pigeons 35Y and 67R, the discrimination between positive and negative trials was strong during both baseline trials (A \rightarrow B) and symmetry trials (B \rightarrow A). For Pigeon 35Y, the response rate disparity between positive and negative symmetry trials was numerically but not reliably greater than the disparity between positive and negative base-

line trials; for Pigeon 67R, the disparity was numerically and reliably smaller on the symmetry trials than on the baseline trials. Overall, both pigeons showed robust symmetrical responding that did not require prior presentation of A \rightarrow B and B \rightarrow A relations with any other training stimuli.

These results with pigeons join those of Tomonaga et al. (1991; Experiment 1) with a chimpanzee in showing that emergent associative symmetry can be obtained with nonhuman animals under proper conditions of training and testing.

EXPERIMENT 2

Because we found robust symmetrical responding in Experiment 1, we wanted to see if intermixing identity matching with arbitrary matching was critical for the result. So, in Experiment 2 we did not intermix identity matching with arbitrary matching; we only gave arbitrary matching prior to testing for symmetry.

METHOD

Participants

Two different feral pigeons were studied. The pigeons were maintained and pretrained as were the pigeons in Experiment 1.

Apparatus

The same apparatus was used as in Experiment 1.

Stimuli

The same four clip-art images were used as in Experiment 1. The counterbalancing of stimuli for both pigeons (Pigeons 27R and 73W) is shown in Table 1.

Procedure

Baseline training. Training was conducted in the same order and manner as in Experiment 1. The ITI was also increased in the same manner as in Experiment 1. For Pigeon 73W, the ITI following negative baseline combinations was increased starting on Day 22 and eventually was increased to a random 20 to 25 s. It was not necessary to increase the ITI for Pigeon 27R. In this experiment, however, there were no identity matching combinations. Only one discrimination ratio was calculated for determining criterion performance.

Baseline training sessions were conducted daily. Each session consisted of 8 blocks of 20 trials, five trials of each arbitrary stimulus combination. Training sessions were conducted until the discrimination ratio was at least 0.80 during a complete training session (there were incomplete sessions; see results). A symmetry testing session was given the following day.

Symmetry testing. Symmetry test sessions consisted of the arbitrary training combinations and the symmetry testing combinations (i.e., the training combinations in the reverse

temporal order). No reinforcement was given on the symmetry testing trials. As in Experiment 1, at least one baseline session during which a pigeon would again have to meet the 0.80 performance criterion was conducted after the initial symmetry testing session before a second symmetry testing session was administered.

Symmetry testing sessions began with a warm-up block that comprised 20 trials: five of each arbitrary stimulus combination. The warm-up block was followed by 7 blocks of 24 trials: five of each arbitrary stimulus combination (20 trials) and one of each testing combination (four trials). Each symmetry testing session comprised 188 trials.

RESULTS

Pigeon 27R

Symmetry Test 1 for Pigeon 27R occurred after 29 days of baseline training (24 incomplete and 5 complete sessions) and there was 1 day of baseline training (0 incomplete and 1 complete session) between Symmetry Test 1 and Symmetry Test 2. Following training with only arbitrary matching, there was good discrimination between the positive and negative baseline combinations, but poor discrimination between the positive and negative symmetry combinations (Table 2). The mean response rates of Pigeon 27R to the positive and negative baseline and symmetry combinations are depicted in Figure 3 (top left). The mean response rate difference between the positive and negative baseline combinations (1.81 pecks per second) was reliably higher than the mean response rate difference between the positive and negative symmetry combinations (0.11 pecks per second) (Table 3); only the baseline training difference was reliable (Table 4).

Pigeon 73W

Symmetry Test 1 for Pigeon 73W occurred after 47 days of training (0 incomplete and 47 complete sessions) and there were 9 days of training (0 incomplete and 9 complete sessions) between Symmetry Test 1 and Symmetry Test 2. Following training with only arbitrary matching, there was good discrimination between the positive and negative baseline combinations, but poor discrimination between the positive and negative symmetry

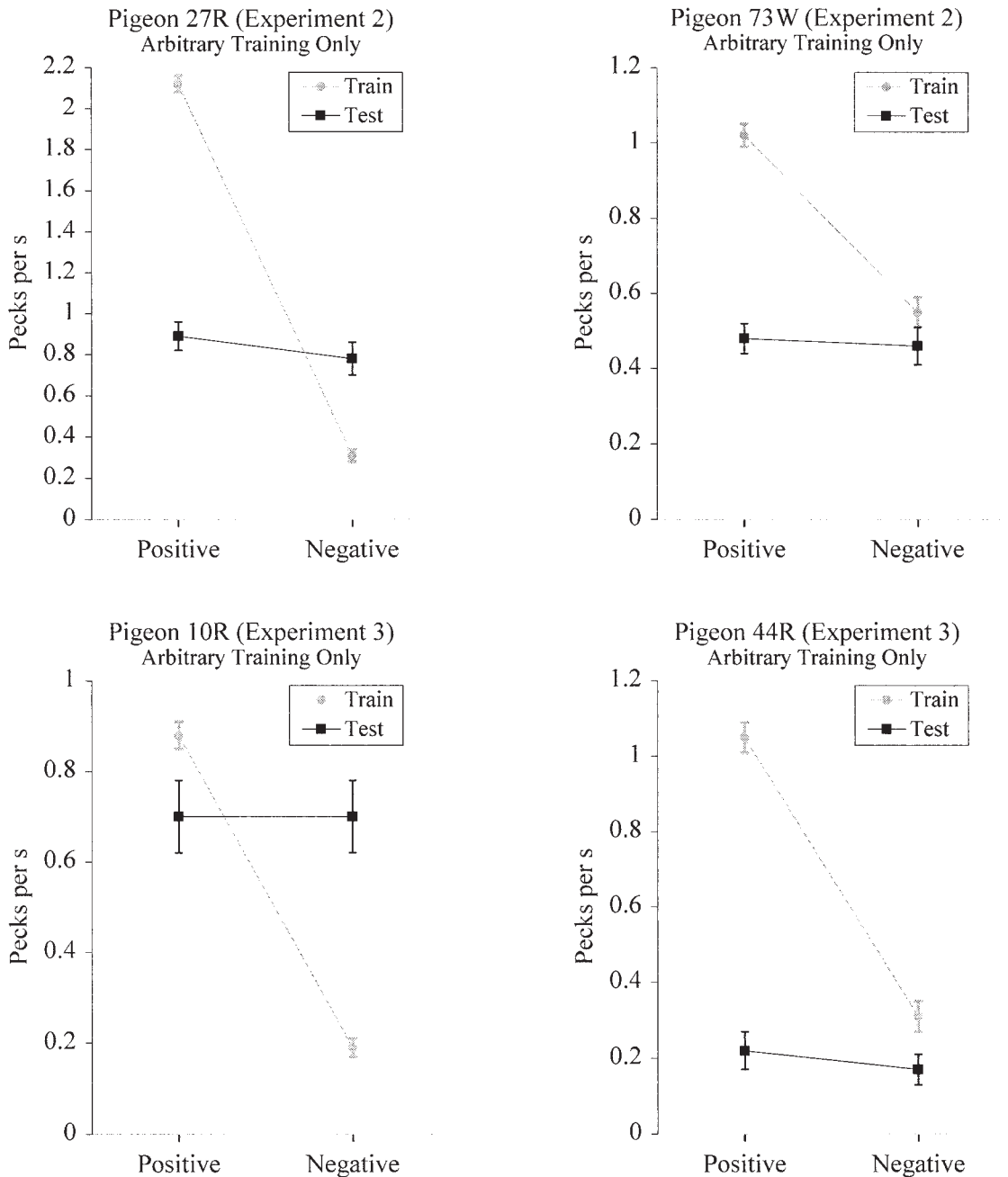


Fig. 3. Individual graphs show the mean response rates in pecks per second for the positive and negative baseline and symmetry combinations during testing for the pigeons that were trained with arbitrary matching trials only. Data for Pigeon 27R (top left; Experiment 2), Pigeon 73W, (top right; Experiment 2), Pigeon 10R (bottom left; Experiment 3), and Pigeon 44R (bottom right; Experiment 3) are depicted.

combinations (Table 2). The mean response rates of Pigeon 73W to the positive and negative baseline and symmetry combinations are depicted in Figure 3 (top right). The mean

response rate difference between the positive and negative baseline combinations (0.47 pecks per second) was reliably higher than the mean response rate difference between

the positive and negative symmetry combinations (0.02 pecks per second) (Table 3); only the baseline training difference was reliable (Table 4).

DISCUSSION

The same successive MTS procedure was used in this experiment as in Experiment 1 with the exception that pigeons learned only arbitrary matching prior to testing for symmetry. Neither pigeon showed symmetrical responding during testing. Response rates to the positive and negative symmetry (B→A) combinations did not differ, despite the fact that strong rate differences held between the positive and negative baseline training (A→B) combinations. So, it appears that learning an identity relation *and/or* seeing all of the discriminative stimuli in both temporal locations may be necessary to produce a symmetrical relation in successive MTS.

EXPERIMENT 3

Because the results of Experiment 1 revealed virtually identical discriminative performances on the A→B baseline training relations and on the B→A symmetrical testing relations, whereas the results of Experiment 2 disclosed no evidence whatsoever for symmetry, we wanted to see if we could repeat the null result of Experiment 2 by again giving only arbitrary matching. After testing for symmetry, we then retrained the pigeons with identity matching trials intermixed with the arbitrary matching trials to see if we could obtain robust symmetrical responding as we had in Experiment 1.

METHOD

Participants

Two different feral pigeons were studied. The pigeons were maintained and pretrained as were the pigeons in Experiments 1 and 2.

Apparatus

Two custom-built operant chambers were used for training and testing (Gibson, Wasserman, Frei, & Miller, 2004). The main differences between the apparatus used in Experiments 1 and 2 and in this experiment were the size of the touchscreen, the type of monitor used to display the stimuli, and the controlling

computer. A 15 in. (2.54 cm) glass touchscreen (452981-000, Elo TouchSystems, Fremont, CA) was used. In addition, the stimuli were displayed on a 15-in LCD flat screen monitor (NEC 1550V, Melville, NY). Each chamber was controlled by an Apple eMac® computer (Z083, Apple, Cupertino, CA). New apparatus was used in Experiment 3 because the equipment in the laboratory was being updated and this new computer system was much faster than the one used in Experiments 1 and 2.

Stimuli

The same four clip-art images were used here as in Experiments 1 and 2. The counterbalancing of stimuli for both pigeons (Pigeons 10R and 44R) can be seen in Table 1.

Procedure

Baseline training (arbitrary combinations only). Trials were conducted in almost the same manner as in Experiments 1 and 2. The only difference was that there was now only a 1-s delay between S1 and S2 rather than a 3.5-s delay. In order to be sure that the pigeons were pecking at a higher rate to each of the positive arbitrary stimulus combinations than to each of the negative arbitrary stimulus combinations, the discrimination ratios were calculated slightly more conservatively in this experiment than they were in Experiments 1 and 2. Here, the number of responses to S2 in each positive stimulus combination (e.g., A1B1) was divided by the number of responses to S2 in each negative stimulus combination (e.g., A2B1) plus the number of responses to S2 in the positive stimulus combination (e.g., A1B1). So, the equation for a discrimination ratio was as follows: $[A1B1 \div (A1B1 + A2B1)]$. This method of calculation resulted in a total of *two* discrimination ratios for the arbitrary matching stimulus combinations rather than only *one* as in Experiment 1 and 2. The ITI was also increased in the same manner as Experiment 1 and 2. The ITI following the negative baseline combinations for Pigeon 44R only was eventually increased to a random 45 to 50 s after 15 days of baseline training and remained there until the end of symmetry testing. It was not necessary to increase the ITI for Pigeon 10R. Each training session consisted of 8 blocks of 20 trials: five of each

arbitrary matching combination. Thus each baseline training session consisted of 160 trials. There were some sessions that were incomplete for both pigeons (see results). Training sessions were conducted until both discrimination ratios were at least 0.80 during a complete session.

Symmetry testing (arbitrary combinations only). When a pigeon reached at least 0.80 on both baseline training discrimination ratios, it was given a symmetry testing session the following day. The testing sessions consisted of arbitrary matching (training) combinations plus the symmetrical testing combinations, and these testing sessions were structured identically to those of Experiment 2. Two symmetry testing sessions were conducted for each pigeon.

Baseline training (arbitrary and identity). Trials were conducted in nearly the same manner as arbitrary-only training. The only difference was that now identity stimulus combinations were intermixed with arbitrary stimulus combinations and a total of six discrimination ratios were calculated (two arbitrary discrimination ratios and four identity discrimination ratios). The ITI was increased in the same manner as in Experiments 1 and 2. The ITI following the negative training combinations for Pigeon 44R was eventually increased to a random 45 to 50 s after 13 days of baseline training and remained there until the end of symmetry testing. The ITI for Pigeon 10R following the negative training combinations was eventually increased to a random 15 to 20 s after 15 days of training and remained there until the end of testing. Each training session consisted of 8 blocks of 24 trials: two of each arbitrary and identity matching combination. Thus each training session comprised 192 trials. Training sessions continued until all six discrimination ratios were at least 0.80.

Symmetry testing (arbitrary and identity). When a pigeon reached criterion on all six discrimination ratios, the following day it was given a symmetry testing session. The testing sessions consisted of the arbitrary and identity matching training combinations in addition to the arbitrary matching combinations in the reverse temporal order (the symmetrical combinations). No reinforcement was given on the symmetrical (testing) trials. Two symmetry testing sessions were again given, separated

by at least one baseline training session, during which the pigeon again had to meet the 0.80 performance criterion. The structure of these two testing sessions was identical to that described for the testing sessions in Experiment 1.

RESULTS

Symmetry Testing (after arbitrary matching only)

Pigeon 10R. Symmetry Test 1 for Pigeon 10R occurred after 36 days of training (4 incomplete and 32 complete sessions) with 4 days of training (0 incomplete and 4 complete sessions) separating Symmetry Test 1 and Symmetry Test 2. Following baseline training with only arbitrary matching, there was good discrimination between the positive and negative baseline combinations, but no discrimination between the positive and negative symmetry combinations (Table 2). The mean response rates of Pigeon 10R to the positive and negative baseline and symmetry combinations are shown in the bottom left panel of Figure 3. The mean response rate difference between the positive and negative baseline combinations (0.69 pecks per second) was reliably higher than the mean response rate difference between the positive and negative symmetry combinations (0 pecks per second) (Table 3); only the baseline training difference was reliable (Table 4).

Pigeon 44R. Symmetry Test 1 for Pigeon 44R occurred after 99 days of training (24 incomplete and 75 complete sessions) with 27 days of training (0 incomplete and 27 complete sessions) separating Symmetry Test 1 and Symmetry Test 2. Following training with only arbitrary matching, there was good discrimination between the positive and negative baseline combinations, but poor discrimination between the positive and negative symmetry combinations (Table 2). The mean response rates of Pigeon 44R to the positive and negative baseline and symmetry combinations are shown in the bottom right panel of Figure 3. The mean response rate difference between the positive and negative baseline combinations (0.74 pecks per second) was reliably higher than the mean response rate difference between the positive and negative symmetry combinations (0.05 pecks per second); only the baseline training difference was reliable (Table 4).

Symmetry Testing (after arbitrary and identity matching)

Pigeon 10R. Symmetry Test 1 for Pigeon 10R occurred after 41 days of training (17 incomplete and 24 complete sessions) with 5 days of training (0 incomplete and 5 complete sessions) separating Symmetry Test 1 and Symmetry Test 2. Following training with both identity and arbitrary matching, there was good discrimination between the positive and negative identity combinations during testing (Table 2); there was also good discrimination between the positive and negative baseline combinations (Table 2), and there was modest discrimination between the positive and negative symmetry combinations (Table 2). The mean response rates of Pigeon 10R to the positive and negative baseline and symmetry combinations are shown in the bottom left panel of Figure 2. The mean response rate difference between the positive and negative baseline combinations (0.48 pecks per second) was reliably higher than the mean response rate difference between the positive and negative symmetry combinations (0.18 pecks per second) (Table 3); each of these differences was reliable (Table 4).

Pigeon 44R. Symmetry Test 1 for Pigeon 44R occurred after 84 days of training (0 incomplete and 84 complete sessions) with 1 day of training (0 incomplete and 1 complete session) separating Symmetry Test 1 and Symmetry Test 2. Following training with both identity and arbitrary matching, there was good discrimination between the positive and negative identity combinations during testing (Table 2); there was also good discrimination between the positive and negative baseline combinations (Table 2); however, there was no discrimination between the positive and negative symmetry combinations (Table 2). The mean response rates of Pigeon 44R to the positive and negative baseline and symmetry combinations are shown in the bottom right panel of Figure 2. The mean response rate difference between the positive and negative baseline combinations (0.73 pecks per second) was much higher than the mean response rate difference between the positive and negative symmetry combinations (0.05 pecks per second) (Table 3); only the baseline training difference was reliable (Table 4).

DISCUSSION

The 2 pigeons in Experiment 3 were trained initially with arbitrary matching alone in order to see if the results of Experiment 2 were replicable. Once again, neither pigeon showed symmetrical responding during testing, even though both strongly discriminated between the positive and negative arbitrary baseline training trials.

Following retraining with intermixed identity and arbitrary matching, 1 pigeon showed reliable symmetrical responding, whereas the other pigeon did not. Pigeon 10R exhibited a reliable difference between its response rates to the positive and negative symmetry testing trials, although that discrimination was much weaker than the pigeon's discrimination between the positive and negative baseline training trials. By contrast, Pigeon 44R exhibited no difference between mean response rates to the positive and negative symmetry testing trials.

Overall, the evidence for symmetry in Experiment 3 following retraining with intermixed identity and arbitrary matching trials after arbitrary matching training only was weaker than that observed in Experiment 1, in which identity and arbitrary matching trials were intermixed from the outset of training. It may be that initial training with arbitrary matching trials and later retraining with intermixed identity and arbitrary matching simply is not as effective in producing symmetry as intermixing identity and arbitrary matching from the outset of training.

GENERAL DISCUSSION

In each of three experiments, we trained pigeons with a forward (A→B) associative relation and later tested them for the presence of an emergent backward (B→A) associative relation. We used a successive MTS procedure that allowed us to show all of the discriminative stimuli in only one spatial location, thereby avoiding the common problem of changing spatial locations that occurs when using n-alternative simultaneous MTS procedures, and allowing us to neutralize temporal location cues.

Even though we avoided differential associations between visual stimuli and their spatial locations, the results of Experiments 2 and 3

suggested that we still must consider possible associations between visual stimuli and their temporal locations that might arise when using a successive MTS design. These two experiments showed that a backward associative relation did not emerge after training symbolic MTS alone. Apparently, the associations between visual stimuli and temporal locations during A→B training disrupt performances on the symmetrical B→A testing relation. In training, Stimulus A is seen only in the first temporal location and Stimulus B is seen only in the second temporal location; in testing, these relations are reversed. When pigeons had experience with all of the stimuli in each temporal location prior to testing (Experiment 1), however, they showed very robust symmetrical responding in successive matching. The requisite experience was accomplished by intermixing identity matching trials with arbitrary matching trials during training.

Experiment 3 further explored the conditions that were necessary to obtain associative symmetry by explicitly varying when or if identity matching was provided in the training that preceded testing. After first training on symbolic successive MTS alone and again finding no evidence of symmetry, the same pigeons then learned identity matching intermixed with their previously learned arbitrary matching. When tested again for symmetry, only 1 of the 2 pigeons showed any evidence of backward associative learning, and this pigeon's performance was not as robust as the behavior of the 2 pigeons in Experiment 1 that had received such intermixed training from the outset. It is possible, therefore, that different training orders are differentially effective in producing symmetrical responding.

If a stimulus is discriminatively different to a pigeon at Time 1 and Time 2 in a successive MTS design, then by intermixing identity and arbitrary matching in Experiment 1, we created what can be interpreted as a many-to-one (MTO) procedure, something known to be effective in producing acquired equivalence effects in pigeons (Uruioli, 1996). The following is a schematic of the design used in Experiment 1, but with the stimuli used at Time 1 in capital letters and the stimuli used at Time 2 in lower case letters:

A1-b1	A2-b2	(Arbitrary)
B1-b1	B2-b2	(Identity)
A1-a1	A2-a2	(Identity)

In this example, if the pigeons see the stimuli in an identity trial as two different stimuli (i.e., A1-a1 instead of A1-A1), then we may have effectively arranged MTO matching in Experiment 1 because A1 and B1 would both be associated with b1. Additionally, because A1 was also paired with a1, this may have allowed for the pigeons to respond to the a1 comparison when presented with the B1 sample in symmetry testing if A1 and B1 had joined an acquired equivalence class as a result of signaling a common reinforced comparison. Given only the present set of experiments, there is no way to determine if the pigeons considered a stimulus at Time 1 to be identical to the same physical stimulus at Time 2—further experiments would need to be conducted. Still, acquired equivalence experiments with nonhuman animals do not train all of the relations simultaneously; the MTO relations are typically learned first. In Experiment 1, that was not the case.

Our goal in giving identity training intermixed with arbitrary matching was not to create a MTO design; rather, it was to circumvent the potentially confounding effects of associations between particular visual stimuli and particular temporal locations. To determine whether symmetry is encouraged by administering MTO training or simply by intermixing identity with arbitrary matching, additional experiments will need to be conducted. One such experiment could involve identity matching, but with *different* stimuli than those involved in arbitrary matching. If this identity training were effective in supporting symmetry, then generalized matching would be implicated in associative symmetry. However, if this training were ineffective in supporting symmetry, then generalized matching would be an unlikely participant in associative symmetry; instead, the temporal generalization decrement analysis that inspired our inclusion of identity matching with the same stimuli as those involved in arbitrary matching would be strengthened.

Assuming that MTO contingencies contributed to the results of Experiment 1 does not, in any event, weaken what certainly appears to

be a robust symmetry effect. MTO is simply a label for a particular training procedure; it is not an interpretation of discriminative behavior. What may guide discriminative behavior is mediated generalization. Mediated generalization often is defined as involving unseen associations between stimuli. Therefore, even if mediated generalization did participate in the bidirectional association between A1 and B1, then such behavioral symmetry may be considered to be emergent, because the specific stimuli were never directly joined in the reverse temporal order.

Another possible explanation for the robust symmetrical result in Experiment 1 might involve our choice of the particular discriminative stimuli. We used complex visual stimuli that inadvertently could have yielded similarities between stimuli such that responding during the symmetry test reflected shared stimulus attributes from training as opposed to symmetry per se. For example, the snail and the flower both have a circular shape. The snail and the pot of the plant were both brown. The green and the blue of the plant and the flower might be deemed to be similar to one another. The color of the plant and the color of the flower stem were the same. And, there was green in both the plant and the butterfly.

Examining Figure 1 and Table 1, it appears that the 2 pigeons in Experiment 1 might have benefited from these similarities, thereby weakening the case for associative symmetry. However, other pigeons experienced the same stimulus assignments, but did not exhibit associative symmetry. For example, Pigeon 35Y (Experiment 1) and Pigeon 44R (Experiment 3) had the same stimulus assignments, and both experienced identity matching intermixed with arbitrary matching during training; but only Pigeon 35Y showed evidence for symmetry. Likewise, Pigeon 67R (Experiment 1) and Pigeon 27R (Experiment 2) had the same stimulus assignments, but only Pigeon 67R showed evidence of symmetry. Therefore, if particular similarities between our discriminative stimuli were crucial to how the pigeons responded during testing, then one should have seen evidence for symmetry in Pigeons 44R and 27R, which was not the case.

The evidence and arguments that we have presented here lead us to conclude that the pigeons in Experiment 1 represent the first

non-ape animals to exhibit a strong and spontaneous backward associative relation ($B \rightarrow A$) when trained on a forward associative relation ($A \rightarrow B$). Indeed, their discriminative responding during testing of the backward relation was virtually identical to their discriminative responding on the forward relation. Under the proper conditions, it now seems possible for an animal to evidence a backward associative relation during testing that is virtually identical to the forward associative relation that is learned during training, without previous training of a symmetrical relation with other discriminative stimuli.

Our experiments specifically sought experimental conditions under which pigeons will exhibit an emergent symmetrical relation without explicit training. Given the results of Experiment 1, it appears that including identity training from the outset is sufficient to produce symmetrical responding. But what are the necessary conditions? Our study and that of Tomonaga et al. (1991) suggest that learning an identity relation might be necessary. Of course, giving identity matching trials allows for all of the discriminative stimuli to be seen in each of the temporal locations. Further research is needed to determine if including identity training from the outset of training is necessary to produce a symmetrical associative relation or if it is merely necessary to show each stimulus in each temporal location (i.e., show the stimuli at both Time 1 and Time 2 during MTS).

Past experimental attempts to find emergent symmetry have been largely unsuccessful. But, by combining the methods used by earlier experimenters who found suggestive evidence of symmetrically discriminative behavior and by reviewing past failures, we have created at least one method that enables pigeons to show associative symmetry in the absence of explicit reinforced training on other symmetrical relations.

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