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Reflexivity: A first demonstration

Melissa Jane Swisher

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By Melissa Jane Swisher

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Reflexivity: A First Demonstration

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

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Approved by Major Professor(s): Peter J. Urcuioli

Approved by: Christopher R. Agnew  6/21/2016

Head of the Departmental Graduate Program
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ABSTRACT


Currently, the emergent relation of reflexivity after training a set of baseline relations has not been demonstrated with any animal—human or nonhuman. True reflexivity can only be demonstrated if no identity (i.e., physically matching stimulus) relations are trained. In six experiments, the emergence of reflexivity and its opposite, anti-reflexivity, were explored. Pigeons received concurrent successive matching training on two or three arbitrary tasks: AB hue-form and BC form-hue (and AC hue-hue) matching. Once they had acquired these tasks, they were tested for BB (form-form) reflexivity or BB’ (form-form) anti-reflexivity matching. Most (10 of 13) pigeons that received three arbitrary tasks showed reflexivity and some (4 of 17) showed anti-reflexivity. Eight pigeons trained on only two arbitrary tasks generally did not show evidence for emergent BB matching: Two showed reflexivity and one showed anti-reflexivity. Tests for stimulus class reorganization yielded mixed results. None of six pigeons demonstrated emergent anti-reflexivity after first showing emergent reflexivity, but three of five pigeons demonstrated emergent reflexivity after first showing emergent anti-reflexivity. In addition to these
novel effects, the data indicate that stimulus class formation depends upon both the baseline contingencies and an apparent identity bias.
INTRODUCTION

There are many ways to measure intelligence, and some involve categorization and conceptual behavior—e.g., an ability to generalize responses within classes and to make different responses to members of different classes (Keller & Schoenfeld, 1950, p. 155). In fact, subjects generalize acquired responses without further training to novel potential class members. This poses a great advantage for human and nonhuman animals so that behavior does not have to be directly trained in every possible situation for appropriate responses to be emitted. William James (1950, p. 459) has often been cited as asserting that “[t]his sense of sameness is the very keel and backbone of our thinking…This sense of identity of the knowing subject is held by some philosophers to be the only vehicle by which the world hangs together.”

Some specific instances of categorization are natural/basic concepts (e.g., Herrnstein, 1979; Herrnstein, Loveland, & Cable, 1976) in which the objects in each set have physical similarities in common, and relational concepts like same/different (e.g., Katz & Wright, 2006; Wasserman & DeVolder, 1993) in which the objects on each trial are either physically similar to, or different from, one another but always differ from every other instance of
the concept. For example, Castro, Wasserman, and Young (2012) used all hot air balloons for one “same” stimulus display with 16 identical icons, and a corresponding “different” display with 16 nonidentical icons in training like a hot air balloon, a sun, a shoe, a clock, etc. They tested with different numbers of icons to see how many icons had to be the same or completely different (e.g., 2, 4, 6, 8, 12, 16, 20, and 24) for pigeons to later respond “same” and “different” to novel displays and found that pigeons were better at these discriminations with more icons than with fewer ones.

Another form of categorization is stimulus equivalence, which is characterized by the interchangeability of arbitrary stimuli that have had some direct or indirect relation to one another. For example, a picture of a dog, the written word *dog*, and the spoken word “dog” have no physical similarities to one another, yet they refer to the same object. That is, they “mean” the same thing.

Sidman and Tailby (1982) proposed a set theory criterion for demonstrating equivalence: The emergent properties of reflexivity, symmetry, and transitivity are required after learning specific “if-then” (conditional) relations. For instance, if subjects learn to match a triangle comparison stimulus to a red sample, a horizontal comparison to a green sample (AB matching, where A = set of sample stimuli and B = set of comparison stimuli), and also learn to match a blue comparison to a triangle sample, and a white comparison to a horizontal sample (BC matching), the subjects may exhibit three emergent (untrained) relations. *Symmetry* requires that the baseline
relations be bidirectional: Given a triangle sample, the subject should select the red comparison rather than the green comparison (BA matching; also CB matching). Subjects should also match a comparison from one baseline relation to a sample from the other baseline relation, which is transitivity. In other words, AC transitivity should emerge from the trained AB and BC relations (e.g., subjects should match the blue comparison to the red sample). The remaining property of stimulus equivalence, and that which is the present concern is reflexivity, the ability to match each stimulus to itself—e.g., matching a red comparison to a red sample and a green comparison to a green sample (AA matching). When all three emergent relations are demonstrated, the trained conditional relations are also equivalence relations.

Reflexivity is similar to a matching concept (e.g., D’Amato, Salmon, & Colombo, 1985; Oden, Thompson, & Premack, 1988; Wright, Cook, Rivera, Sands, & Delius, 1988) or generalized identity matching (e.g., Hogan, Edwards, & Zentall, 1981; Holth, 2003). These refer to situations in which subjects are explicitly taught in training to select comparison stimuli that are physically identical to sample stimuli and, then, tested to see if they can now generalize this performance by matching new stimuli to one another. For example, a subject might learn to select a green comparison stimulus (but not a red comparison stimulus) when a green sample is presented and to select a red comparison stimulus (but not a green comparison stimulus) when a red sample is presented. Later, if presented with blue and yellow matching stimuli, selecting a blue comparison in the presence of a blue sample and selecting a
yellow comparison in the presence of a yellow sample would demonstrate a “matching concept” or generalized identity matching.

Indeed, Sidman and Tailby (1982) accept generalized identity as evidence for reflexivity in humans in part because all human participants in any type of experiment have a pre-experimental history of identity matching. However, Saunders and Green (1992, p. 236) cautioned against using generalized identity as evidence for reflexivity: The equivalence relation is defined by the contingencies involved in conditional discrimination learning, not by a past history of learning to match physically similar stimuli to one another. In other words, participants should only match stimuli included in baseline training, not any other novel stimuli.

Horne and Lowe (1997, p. 276) expanded upon this and concluded that no human (or nonhuman) subject had ever demonstrated equivalence given that previous evidence for reflexivity, one of its defining properties according to Sidman and Tailby (1982), has been based on generalized identity results. A subject should match only those baseline stimuli to themselves for a true reflexivity test. To continue with the previous example, after training red-triangle and green-horizontal (AB) relations as well as triangle-blue and horizontal-white (BC), the subject should now match a red comparison to a red sample, a green comparison to a green sample (AA), a triangle comparison to a triangle sample, a horizontal comparison to a horizontal sample (BB), a blue comparison to a blue sample, and a white comparison to a white sample (CC). They should not, however, match a vertical comparison to a vertical sample or
a dot comparison to a dot sample (DD) because these stimuli were not part of training.

Horne and Lowe (1997) are correct that no subject has shown evidence for true reflexivity—as such a test has either not been possible or has never been done. In fact, generalized identity training and/or testing tends to be used for humans to familiarize the participants with the experimental procedures during pretraining in equivalence studies (i.e., prior to introducing the experimental stimuli—e.g., Dube, Mcllvane, Maguire, Mackay, & Stoddard, 1989; Saunders, Drake, & Spradlin, 1999; Sidman & Tailby, 1982). For example, Pilgrim and Galizio (1990) tested for identity matching and found that their college students showed evidence for it with the baseline stimuli. Although identity matching was not explicitly trained in their experiment, it would be odd to assume that the participants did not have pre-experimental histories of such training with other stimuli.

In short, it may be impossible to differentiate between reflexivity and generalized identity with human participants, even with very young children (see, for example, Wasserman & Castro, 2012). Human participants from a very early age learn about same (identity) and different (oddity) relations. Consequently, the fact that they can immediately match novel stimuli to themselves in the laboratory (e.g., Brown, Brown, & Poulson, 1995; de Alcantara Gil, de Oliveira, & Mcllvane, 2011; Gollin & Shirk, 1966; Lipsitt & Serunian, 1963; Saunders, Johnston, Tompkins, Dutcher, & Williams, 1997; Saunders, Wachter, & Spradlin, 1988; Shimizu, 2006) is likely to be evidence
only for generalized identity matching, not for reflexivity (e.g., Sidman & Tailby, 1982; Sigurdardottir, Green, & Saunders, 1990; Steele & Hayes, 1991). A more promising approach is to use nonhuman subjects whose pre-experimental histories can be monitored and controlled to ensure that any demonstration of reflexivity is not simply a reflection of past identity training.

Previous research on identity and oddity concepts with nonhuman animals has mostly been conducted with $n$-alternative matching or oddity tasks (e.g., da Silva Barros, de Faria Galvão, & McIlvane, 2002; Kastak & Schusterman, 1994; Wright, 1997; Zentall, Edwards, Moore, & Hogan, 1981; Zentall, Hogan, & Edwards, 1980; Zentall, Hogan, & Holder, 1974). These procedures have been somewhat successful for finding transfer of matching performance to new visual stimuli, but they have been far less successful for finding evidence for equivalence relations (e.g., Hogan & Zentall, 1977; Khallad, 2004; Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982).

In two-alternative matching-to-sample with pigeons, a sample stimulus appears on the center key in a three-key operant chamber and remains on until a pigeon pecks at it one or more times. In the zero-delay version of the task, the sample stimulus then turns off and the two comparison stimuli appear immediately on the left and right keys. For identity (or oddity) tasks, one of the comparison stimuli matches the sample stimulus and the other comparison stimulus does not. Responding to the matching (nonmatching) comparison stimulus is “correct” and results in food while responding to the nonmatching (matching) comparison stimulus is “incorrect” and results only in the intertrial
interval or a time-out period equal to the food duration. Performance is measured by the percentage of correct choices, which increases as the pigeons learn the reinforcement contingencies.

More recently, successive matching-to-sample has been used to investigate emergent same/different concepts and equivalence relations (e.g., Katz & Wright, 2006; Urcuioli, 2008). In successive (or go/no-go) matching, the sample is displayed on the center key for a specific amount of time and often ends with a response after that time has elapsed (viz., a fixed interval schedule). A short, blank interstimulus interval then follows and ends with the onset of a single comparison stimulus typically on the same key. The comparison stimulus is also displayed for a specific amount of time (e.g., 5 s) timed either from its onset or from the first response to it. On reinforced (e.g., matching) trials, the first peck after the comparison interval has elapsed turns it off and produces food. On nonreinforced (e.g., nonmatching) trials, the comparison turns off automatically without food after the interval has elapsed. With training on this type of procedure, the pigeons eventually confine most of their pecks to the “correct” comparison stimuli, refraining from pecking the “incorrect” comparison stimuli.

The main differences between two-alternative and successive matching-to-sample (MTS) procedures are that 1) sample and comparison stimuli always appear in different spatial locations in two-alternative MTS but typically in the same location in successive MTS; and 2) fewer extinction (i.e., incorrect) trials are encountered as acquisition continues in two-alternative MTS, whereas they
are constant (viz., always half of the trials) in successive MTS. There is
evidence that these differences are important when examining emergent
relations in nonhuman animals (e.g., Urcuioli, 2008).

Frank and Wasserman (2005) were the first to use successive MTS to
test for the emergent relation of BA symmetry in pigeons after training them on
AB matching along with AA and BB successive identity matching. Their stimuli
were color clipart pictures of a plant, a flower, a butterfly, and a snail. In the
arbitrary (AB) task, they matched a butterfly comparison to a snail sample and
a plant comparison to a flower sample. In the two identity (AA and BB) tasks,
their pigeons matched a snail comparison to a snail sample, a butterfly
comparison to a butterfly sample, a flower comparison to a flower sample, and
a plant comparison to a plant sample. AA and BB identity tasks were included
so that pigeons could see each stimulus both as a sample and as a
comparison (i.e., in each ordinal position) prior to testing. Had they only
trained the AB task and immediately tested for BA symmetry, the pigeons
would have only seen the A stimuli as samples (i.e., first in a trial) and the B
stimuli as comparisons (i.e., second in a trial), so the A stimuli appearing as
comparisons and the B stimuli appearing as samples in testing would be novel.
The inclusion of AA and BB identity tasks in training avoided this potential
problem.

Frank and Wasserman tested for BA symmetry by presenting periodic,
nonreinforced probe trials that were the reverse of the trained arbitrary (AB)
matching sequences. For example, they presented a snail comparison after a
butterfly sample and a flower comparison after a plant sample. When all of the baseline tasks were trained simultaneously, pigeons demonstrated symmetry—responding far more to a snail comparison after a butterfly than after a plant sample, and responding far more to a flower comparison after a plant than after a butterfly sample. This was the first clear demonstration of symmetry with pigeons.

Urcuioli (2008, Experiment 3) was able to replicate Frank and Wasserman’s (2005) symmetry results with green and red hues and triangle and horizontal lines forms. He, too, simultaneously trained AA hue identity, BB form identity, and AB hue-form arbitrary matching and tested for BA form-hue symmetry. Using simple hue and form stimuli rather than more complex color clipart images controls for potential similarities across stimuli that could produce symmetry-like results due to mere stimulus generalization. Most pigeons still responded more frequently to the reverse of the reinforced AB relations than to the reverse of the nonreinforced AB relations, demonstrating symmetry.

In another experiment (Urcuioli, 2008, Experiment 4), Urcuioli tested Frank and Wasserman’s (2005) “familiarity” hypothesis regarding the two “extra” identity tasks. If AA and BB identity are only necessary in order to allow pigeons to see each stimulus in each ordinal position prior to testing, then symmetry should also be observed after concurrent training with either AA’ oddity and BB identity or AA identity and BB’ oddity. Urcuioli used the former tasks along with AB hue-form matching in order to test for BA symmetry.
Rather than observing BA symmetry, however, he found that pigeons responded more frequently to the reverse of the nonreinforced AB relations than to the reverse of the reinforced AB relations. In other words, pigeons responded more frequently to a green comparison than a red one after a triangle sample and more frequently to a red comparison than a green one after a horizontal lines sample in testing when responding to red sample-triangle comparison and green sample-horizontal comparison combinations had been reinforced in training. He called this emergent relation “anti-symmetry” given that it was the opposite of the predicted BA symmetry relation. It seemed that training the AA and BB tasks accomplished something more than just familiarizing the pigeons with each stimulus in each ordinal position.

Using the two-alternative matching-to-sample procedure, Hogan and Zentall (1977) and Sidman et al. (1982) tested for symmetry with pigeons, rhesus monkeys, and baboons. They did not find symmetry because their procedures did not take into account the ordinal position of the stimuli. That is, former samples from baseline became comparisons and former comparisons became samples on symmetry probes. The subjects had never seen the stimuli in these positions prior to testing and were then unable to respond appropriately. For nonhumans, a stimulus as a sample is not the same as that nominal stimulus appearing as a comparison.

Urcuioli’s (2008) Theory of Stimulus-Class Formation

Given the unexpected “anti-symmetry” results, Urcuioli (2008) developed a theory of pigeons’ stimulus class formation to account for both
symmetry and anti-symmetry and to predict other equivalence relation effects obtained in successive matching (including reflexivity under investigation here). The first assumption of the theory is that pigeons attend not only to the nominal matching stimuli but also to their physical location and ordinal position within a trial. To the experimenter, the stimulus is often defined simply as the nominal stimulus: Red is red, green is green, triangle is triangle, and horizontal is horizontal. To the pigeon, however, the stimuli are a combination of what is presented, where it is presented, and when it is presented. For example, red is not just red but red-on-the-center-key-in-the-first-ordinal-position (i.e., as the sample). Stimuli can be designated using notations that take these additional properties into account. Thus, red as a sample on the center key is c-R1, red as a comparison on the center key is c-R2, green as a sample on the center key is c-G1, and so on. In successive matching, all of the stimuli typically appear on the center key so it is acceptable to delete the notation for this invariant feature and simply use the functional stimulus designation as the nominal stimulus and its ordinal position: a red sample is R1.

The second assumption of the theory is that the nature of successive matching results in stimulus classes containing the sample and comparison on the reinforced baseline trials. Thus, if pigeons obtain reinforcement for responding to a triangle comparison following a red sample in AB matching, then the resulting stimulus class would be composed of that red sample and triangle comparison: [red sample, triangle comparison] or [R1, T2]. Likewise, if responding to a horizontal comparison after a green sample is reinforced in AB
matching, a \([G1, H2]\) class would form. Thus, for every two-sample, two-comparison baseline task, there would be two 2-member stimulus classes.

The third assumption of the theory is that reinforcement constantly juxtaposed with nonreinforcement facilitates the separation of stimuli into different stimulus classes like those mentioned above. Half of the trials in successive matching always end in food (i.e., are reinforced) and half of the trials always end in extinction (i.e., are nonreinforced). The corresponding extinction trial for the reinforced red sample-triangle comparison combination would be the red sample-horizontal lines comparison combination. Similarly, responding to a triangle comparison after a green sample would not be reinforced.

The fourth assumption of the theory states that common elements will cause their respective smaller classes to merge into larger ones. Rather than derive the prediction for symmetry, which has been demonstrated several times now, a theoretical prediction for AA reflexivity (based on a procedure used by Sweeney & Urcuioli, 2010) will now be derived to illustrate these theoretical mechanics. These are depicted in Figure 1 (a) and (b) which shows the six 2-member classes hypothesized to develop from AB, BA, and BB successive matching and the elements common to more than one class (ellipses), respectively. If the common elements merge the six 2-member classes together, Figure 1 (c) shows they become two 4-member stimulus classes.
These assumptions of Urcuioli’s (2008) theory make clear, testable predictions about different emergent relations that should arise from different baseline training tasks. When training these AB hue-form, BA form-hue, and BB form identity relations, reflexivity is predicted (Urcuioli & Swisher, 2012b). Specifically, all of the relations in the 4-member classes were trained except matching a red comparison to a red sample from class [R1, T1, R2, T2] and a green comparison to a green sample from class [G1, H1, G2, H2]. Nonetheless, pigeons should respond more frequently to a red comparison after a red sample, and to a green comparison after a green sample, because the elements of each sample-comparison pair belong to the same classes. In fact, Urcuioli and Swisher reported that five of the six pigeons trained and tested in this fashion did show evidence for this emergent relation. This is excellent evidence that pigeons can match identical stimuli to one another without explicit training to do so. However, as mentioned before, it is not evidence for true reflexivity because one of the baseline training tasks was BB (form-form) identity matching. In other words, the data are also consistent with generalized identity matching.

Training pigeons on three arbitrary baseline tasks and testing for emergent identity matching in a successive matching procedure is required in order to yield a true demonstration of reflexivity. The contribution of Urcuioli’s (2008) theory is that ordinal position is an important part of the functional stimulus for the pigeon. Experiencing trials in baseline training on which the form samples and comparisons appear in the same positions as on reflexivity
probe trial makes it possible for pigeons to demonstrate this emergent relation.

The theoretical importance of such a finding cannot be underestimated, and
was the primary goal of this dissertation.
EXPERIMENT 1

Sweeney and Urcuioli (2010), Urcuioli (2011), and Urcuioli and Swisher (2012b) demonstrated that pigeons would respond preferentially to identical sample and comparison stimulus combinations on emergent-relations probe trials if those stimuli belonged to the same stimulus classes. For instance, Sweeney and Urcuioli (2010) trained pigeons on AB, BA, and BB successive matching in which they matched a triangle comparison (T2) to a red sample (R1) and a horizontal comparison (H2) to a green sample (G1) for their AB task. They matched a red comparison (R2) to a triangle sample (T1) and a green comparison (G2) to a horizontal sample (H1) for their BA task. They also matched a triangle comparison (T2) to a triangle sample (T1) and a horizontal comparison (H2) to a horizontal sample (H1) for their BB task. The classes hypothesized to arise from these contingencies would be [R1, T2, T1, R2] and [G1, H2, H1, G2], as depicted in Figure 1 (c), from which it was predicted that pigeons would respond more frequently to a red comparison after a red sample (R1→R2) and to a green comparison after a green sample (G1→G2), and, in fact, they did. However, because the form identity (BB) relation was directly trained, just as in Urcuioli and Swisher (2012b), the results
of the reflexivity (hue-hue or AA matching) probes could be due to generalized identity matching (cf. Urcuioli, 2011).

In the present experiment, the baseline contingencies did not include training on any identity relations. Thus, any differential responding on a reflexivity test would not be explicable in terms of generalized identity matching. Pigeons in Group R were trained on AB, BC, and AC successive matching prior to testing for reflexive BB matching (see Table 1). Specifically, they learned in AB matching to match a triangle comparison (T2) to a red sample (R1) and a horizontal comparison (H2) to a green sample (G1). They also learned in BC matching to match a blue comparison (B2) to a triangle sample (T1) and a yellow comparison (Y2) to a horizontal sample (H1). Finally, they learned in AC matching to match a blue comparison (B2) to a red sample (R1) and a yellow comparison (Y2) to a green sample (G1). Training should result in six 2-member stimulus classes: [R1, T2], [G1, H2], [T1, B2], [H1, Y2], [R1, B2], and [G1, Y2]—see Figure 2 (a). Class merger via common elements should occur through the red sample (R1), blue comparison (B2), green sample (G1), and yellow comparison (Y2) stimuli as shown in Figure 2 (b). Class merger yields two 4-member stimulus classes as shown in Figure 2 (c): [R1, T2, T1, B2] and [G1, H2, H1, Y2]. Reflexivity involves matching a triangle comparison to a triangle sample and a horizontal comparison to a horizontal sample. According to the theory, the Group R pigeons should respond preferentially to the matching comparisons on test trials (cf. arrows in Figure 2 (c)) because the triangle sample and comparison belong to one 4-member
stimulus class [R1, T2, T1, B2] and the horizontal sample and comparison belong to the other 4-member stimulus class [G1, H2, H1, Y2].

To be sure that the baseline contingencies were responsible for any observed reflexivity, a control group received training on only two successive matching tasks: AB and BC (see Table 1). Group C pigeons learned to match a triangle comparison (T2) to a red sample (R1) and a horizontal comparison (H2) to a green sample (G1) for their AB task. They also learned to match a blue comparison (B2) to a triangle sample (T1) and a yellow comparison (Y2) to a horizontal sample (H1) for their BC task. This training should result in four 2-member stimulus classes: [R1, T2], [G1, H2], [T1, B2], and [H1, Y2]. There are no common elements across these four classes, so class merger is not possible (see Figure 3). Consequently, the triangle sample and comparison are not in the same stimulus class, nor are the horizontal sample and horizontal comparison. Thus, Group C pigeons should not match these physically identical stimuli to one another in testing despite having seen the triangle and horizontal form stimuli both as samples and comparisons in training. That is, the predicted, nondifferential test-trial responding for these pigeons cannot be attributed to stimulus novelty/generalization decrement.

Method

Subjects

Eleven White Carneau pigeons obtained from Double “T” Farms (Glenwood, IA) participated in the study. They were all experimentally naïve and were given free access to food (Purina Pro11 mixed grain), water, and grit
upon arrival to the laboratory. It took 6-85 days for the pigeons to reach a stable, free-feeding weight, after which each was reduced to 80% of its free-feeding weight prior to their participation in the experiment. Pigeons were individually housed in a colony room with a 14 h – 10 h light-dark cycle (lights on at 07:00) and with water and grit freely available. The pigeons were maintained at 80% of their free-feeding weights by providing mixed grain during their experimental sessions and on the one day per week during which the experiment was not conducted. Prior to the start of the experiment, they were assigned to either Group R (Reflexivity) or Group C (Control). Initially, there were six pigeons in Group R and five pigeons in Group C, but one Group C pigeon died a few days after starting the experiment.

**Apparatus**

Two pigeon operant chambers consisting of three-key (Model PIP-016) panels inside Model SEC-002 enclosures (BRS/LVE, Laurel MD) were used. Only the center keys were used. The form stimuli were a solid, inverted white triangle on a black background and three white, horizontal lines on a black background displayed by a stimulus projector mounted behind the center keys; the hue stimuli were red, green, yellow, and blue homogenous fields (BRS/LVE Pattern 692). The house light (GE No. 1829 bulb) was 7.6 cm above the center key (2.5-cm diameter), and the light from the bulb was directed toward the ceiling by a metal housing covering the bottom of the bulb. A 5.8 cm x 5.8 cm opening below the center key permitted access to a rear-mounted food hopper. The opening was illuminated by a miniature bulb (ESB-28) when the
food hopper was raised. A continuously running blower fan attached to the outside of each chamber provided masking noise and ventilation. All experimental events were controlled and recorded by IBM-compatible computers.

**Procedure**

**Preliminary training.** All pigeons had key pecking shaped by the method of successive approximations to three diagonally-aligned dots on the center key. Then they received one 60-trial session with triangle and horizontal forms, one session with red and green hues, and one session with blue and yellow hues. There was a 10-s intertrial interval (ITI) between stimulus presentations, and the hopper durations after each stimulus was pecked ranged from 2-5 s across sessions to maintain the birds at their individual 80% body weights. The hopper duration was constant within a session. Next, pigeons received one 60-trial session on fixed interval (FI) 2 s schedule of reinforcement, one session on FI 3 s, and one session on FI 5 s. They then received two sessions on FI 5 s in which only half of the trials ended in food. This progression from FI 2 s to FI 5 s with partial reinforcement occurred for the forms and for both sets of hues.

**Successive matching acquisition.** Pigeons in Group R concurrently learned an AB hue-form task, a BC form-hue task, and an AC symbolic hue-hue task (see Table 1). Pigeons in Group C concurrently learned the AB hue-form task and the BC form-hue task; they did not receive training on the AC symbolic task.
All samples and comparisons appeared singly on the center key. Each successive matching trial began with a sample on the center key. The first sample peck initiated a 5-s interval after which a sample peck turned off the stimulus and initiated a 1-s interstimulus interval. Once the interval terminated, the comparison stimulus appeared. If the trial was scheduled to end in food (reinforced), the pigeon had to complete an FI 5 s schedule. If the trial was not scheduled to end in food (nonreinforced), the comparison turned off after 5 s had elapsed. Food presentations on reinforced trials could last 2-6 s. The food hopper was raised to allow the bird to eat for the same amount of time throughout a session (e.g., 2 s), but the time could differ across sessions to maintain each of the birds at its 80% weight. Regardless of the trial outcome, the house light turned off and stayed off for the first 14 s of the 15-s ITI. In the last second of the ITI, the house light was turned on and stayed on throughout the trial.

Group R had 96 total trials in a session: 32 AB hue-form (eight R→T, eight R→H, eight G→T, and eight G→H) trials, 32 BC form-hue (eight T→B, eight T→Y, eight H→B, and eight H→Y) trials, and 32 AC symbolic (eight R→B, eight R→Y, eight G→B, and eight G→Y) trials. Group C had 64 total trials in a session: 32 AB hue-form (eight R→T, eight R→H, eight G→T, and eight G→H) trials and 32 BC form-hue (eight T→B, eight T→Y, eight H→B, and eight H→Y) trials. These trials occurred randomly within a session with the constraint that no specific sample-comparison combination could occur more than three times in a row.
The specific contingencies for Groups R and C are displayed in Table 1. Groups R and C matched a triangle comparison stimulus to a red sample stimulus and a horizontal comparison stimulus to a green sample stimulus in their hue-form (AB) task. Both also matched a blue comparison stimulus to a triangle sample stimulus and a yellow comparison stimulus to a horizontal sample stimulus in their form-hue (BC) task. Group R learned a third, AC task in which they matched a blue comparison stimulus to a red sample stimulus and a yellow comparison stimulus to a green sample stimulus. The other sample-comparison combinations were never followed by food (e.g., a horizontal comparison after a red sample, a triangle comparison after a green sample, a yellow comparison after a horizontal sample, etc.).

Discriminative performances were measured by comparison responding on reinforced (“matching”) trial types versus comparison responding on nonreinforced (“nonmatching”) trials with the expectation that pigeons should confine most of their responses to the comparison stimuli on reinforced trials. A discrimination ratio (DR) for each of the three tasks (AB hue-form, BC form-hue, and AC symbolic) for Group R and for both tasks (AB hue-form and BC form-hue) for Group C was used to assess acquisition. DRs were calculated by dividing the total number of pecks to the comparison stimuli on reinforced (matching) trials by the total number of pecks to the comparison stimuli on both reinforced and nonreinforced trials. Only those pecks occurring within 5 s of comparison onset were used in these calculations. A DR of 1.00 indicates perfect discrimination, and a DR of .50 indicates no discrimination (viz.,
responding equally to all comparison stimuli). The acquisition criterion for each of the three (two) tasks was .80 for Group R (Group C) for five of six successive sessions. Once the criterion had been met, all pigeons completed a minimum of 10 sessions of overtraining during which the last five of six sessions again met criterion. The overtraining sessions were run to ensure stability of the baseline performance.

**Successive matching testing.** After finishing overtraining, BB (form-form) reflexivity testing was begun. Test sessions were conducted as pairs of two successive sessions separated by five (of six) baseline sessions at criterion until eight test sessions were completed. Test sessions were composed of 96 baseline trials and eight BB probe trials (Group R) or 64 baseline trials and eight BB probe trials (Group C). The BB probes were nonreinforced regardless of responding, and they were dispersed relatively evenly throughout a test session with the constraints that every baseline trial type appeared once prior to the first BB probe and that at least six baseline trials intervened between successive probes. The four BB probe types were T1→T2, T1→H2, H1→T2, and H1→H2, as shown in the far right column of Table 1. Each was presented twice in a test session, with the comparison stimulus terminating 5 s after onset. The dependent variable was the rate of responding to the comparison stimulus on these BB probes. Group R pigeons were predicted to respond more frequently to the comparison stimuli on matching probe trials (check-marked trials in Table 1) than to the comparison stimuli on nonmatching probe trials, but Group C pigeons were predicted to
respond roughly equally (i.e., nondifferentially) to comparison stimuli on the probe trials.

One-way analysis of variance (ANOVA) was used to evaluate each individual subject’s test data for the eight test sessions. Eight randomly determined AB hue-form trials (two of each type) served as the baseline rate comparison for the eight probe trials within a session. Type I error rate was set at .05 (Rodger, 1975) on a per-decision basis.

**Results**

**Acquisition and Baseline Performance**

All 10 pigeons met the .80 DR criterion for all three (AB hue-form, BC form-hue, and AC symbolic) or two (AB hue-form and BC form-hue) tasks. Group R pigeons initially met criterion after an average of 23.2 sessions for the AB hue-form task, 30.3 sessions for the BC form-hue task, and 23.0 sessions for the AC symbolic task. There was a statistically significant difference for meeting criterion on the three tasks, $F(2, 10) = 3.54$, due to the difference between the form-hue and the remaining two tasks. Group C pigeons initially met criterion after 28.8 sessions for the AB hue-form task and 55.3 sessions for the BC form-hue task. This difference was not statistically significant, $F(1, 3) = 4.90$.

Figure 4 shows acquisition for each Group R pigeon on all three tasks prior to the first two test sessions. The acquisition curves (plotted over blocks of five sessions) were generally comparable with the exception that learning the BC (form-hue) relations lagged behind the other two (AB hue-form and AC
symbolic) relations for R2, R3, R4, and R6. Nevertheless, they, like the other pigeons, eventually met the .80 DR criterion for all three tasks simultaneously.

Figure 5 shows the corresponding acquisition data for each Group C pigeon on its two baseline tasks. Noticeably, learning the BC (form-hue) relation was much slower than the AB hue-form relation for three (C1, C2, and C4) of the four pigeons, although they all met criterion to proceed to testing.

Over the last five sessions of overtraining prior to the first two test sessions, the DRs for Group R were .90 for the AB hue-form task, .90 for the BC form-hue task, and .91 for the AC symbolic task. There was not a statistically significant difference between tasks, $F(2, 10) = .18$. The corresponding DRs for Group C were .93 for the AB hue-form task and .91 for the BC form-hue task. This difference was not statistically significant, $F(1, 3) = .55$. In short, pigeons in both groups performed their respective baseline tasks at high levels of accuracy prior to testing.

During testing, most of the baseline DRs remained at or above the .80 criterion. There were 15 instances out of 184 in which the DRs fell below .80, most above .72, but two at .64 and .69. Most (11) of these belonged to R5 and were limited to the BC (form-hue) and AC symbolic tasks.

**Test Performances**

Figures 6 and 7 show the averaged results over the eight reflexivity sessions for each pigeon in Groups R and C, respectively. Plotted are the comparison pecks per second on the AB hue-form baseline trials (open circles) and the nonreinforced BB form-form probe trials (filled circles).
The baseline data are from four reinforced (“matching”) AB trials and four nonreinforced (“nonmatching”) AB trials in each test session; each datum point represents an average of 32 trials (4 trials per session x 8 test sessions). All of the pigeons responded more to the comparison stimuli on the matching (reinforced) baseline trials than to the comparison stimuli on the nonmatching (nonreinforced) baseline trials, showing that these discriminations remained intact during testing.

The BB (form-form) probe trials are the four matching (two each of T1→T2 and H1→H2) and four nonmatching (two each of T1→H2 and H1→T2) trials in each test session. The comparison pecks per second were averaged across the four matching and across the four nonmatching probes over all eight test sessions (32 matching and 32 nonmatching trials total). All six Group R pigeons responded more frequently to the comparison stimuli on matching probe trials than on nonmatching probe trials. These differences in probe response rates were significantly different from one another for five pigeons (R2, R3, R4, R5, and R6), $F_s(1, 62) = 18.42, 38.56, 8.81, 32.54, \text{ and } 33.86$, respectively. It was not for R1, $F(1, 62) = 3.60$. Also as predicted, two of four pigeons in Group C (C1 and C4) responded nondifferentially on probe trials—i.e., about equally often to the comparison stimuli on matching as on nonmatching probe trials, as predicted, $F_s(1, 62) = 1.06 \text{ and } .29$. However, contrary to prediction, C2 and C3 responded *differentially* on the probe trials: They pecked the comparison stimuli on matching probe trials more often than
on nonmatching probe trials. These differences were statistically significant, $F_s(1, 62) = 8.53$ and $8.29$, respectively.

**Discussion**

Most pigeons in Group R demonstrated reflexivity by responding more to the comparisons on the matching $T_1 \rightarrow T_2$ and $H_1 \rightarrow H_2$ trials than to the comparisons on the nonmatching $T_1 \rightarrow H_2$ and $H_1 \rightarrow T_2$ trials, as predicted by Urcuioli’s (2008) theory. This emergent relation was predicted because the stimulus classes that supposedly formed from baseline training – $[R_1, T_2, T_1, B_2]$ and $[G_1, H_2, H_1, Y_2]$ – each contained the elements of the matching combinations. Specifically, the triangle sample ($T_1$) and triangle comparison ($T_2$) belong to one class and, thus, should be matched to one another. Likewise, the horizontal sample ($H_1$) and horizontal comparison ($H_2$) belong to the other class and should be matched to one another. This is the first demonstration of reflexivity that cannot be alternatively explained by a history of identity training (i.e., by generalized identity matching; cf. Sweeney & Urcuioli, 2010; Urcuioli, 2011) or by transitivity (e.g., Urcuioli & Swisher, 2012b). A specific history of arbitrary baseline training was sufficient for pigeons to match the form stimuli to themselves.

While the Group R pigeons were predicted to demonstrate reflexivity in the present experiment, the Group C pigeons were not—but two did. Typically, it is quite difficult to get nonhuman animals to match physically identical stimuli to one another. Wright and Katz (2006) found that monkeys demonstrated full concept or same/different learning only after training with 128 unique display
combinations of items (e.g., color pictures of people, cats, buildings, and flowers). Pigeons did not demonstrate full concept learning (i.e., pecking “same” to the bottom picture in a two-stimulus display for two pictures that were physically identical and pecking “different” to a white triangle when two pictures that were not physically identical were displayed together) until they had been trained with 256 unique display combinations of items. Unlike the many exemplars used in the Wright and Katz experiment, the stimuli in the present experiment were simple forms and hues involved in only a small number of display combinations during training – none of which involved “same” combinations – and only 4 display combinations in testing—that is, the forms (i.e., triangle and horizontal lines) were presented as both samples and comparisons on the reflexivity probe trials.

Prior to testing, it numerically took both groups of pigeons longer to acquire the BC task than the other task(s). In two-alternative matching-to-sample tasks, it is not uncommon for pigeons to learn form-sample tasks slower than hue-sample tasks (Carter & Werner, 1978). In fact, this difference in acquisition is due to discriminating form samples successively across trials. Discriminating forms simultaneously or hues successively is not as difficult. The AC task involves discriminating different hues as samples and comparisons while the AB task involves discriminating hue samples and form comparisons. The BC task is different in that it involves discriminating form samples and hue comparisons. The relative difficulty mastering the BC task is most likely due to discriminating the form samples.
The Group R and Control group pigeons also had a more difficult form-form discrimination on reflexivity probe trials (cf. Carter & Eckerman, 1975) than even Sweeney and Urcuioli’s (2010) and Urcuioli and Swisher’s (2012b) pigeons that had hue-hue discriminations on reflexivity probe trials. The Group C pigeons should not have shown reflexivity (cf., Urcuioli, 2008) without the elements for class merger. Why did they?

If pigeons C2 and C3 ignored the ordinal position of the stimuli, their stimulus classes could be designated [R, T] and [G, H]. Under these circumstances, they would be able to match the triangle comparison to the triangle sample and the horizontal comparison to the horizontal sample. Alternatively, they may be showing an identity bias in which they matched each stimulus to itself on the basis of physical similarity and not stimulus class formation (cf. Hogan, Edwards, & Zentall, 1981; Wasserman & Castro, 2012; Zentall, Edwards, Moore, & Hogan, 1981). If C2 and C3 had ignored the ordinal position of the stimuli, then they should also demonstrate the emergent relation of symmetry with the [R, T] and [G, H] stimulus classes. On the other hand, an identity bias would predict that they would not show evidence for symmetry, a result that would indicate no stimulus-class formation.

Experiment 2 was designed to address a number of questions arising from the test results of both Group R and Group C. First, would Group R’s performance on reflexivity probes be sensitive to a change in their baseline contingencies? Specifically, if the baseline contingencies provided the elements for stimulus class formation, then reversing the BC task should result
in evidence for class reorganization and a different pattern of test results (see below). In the present experiment, Group R pigeons responded more frequently to comparison stimuli that physically matched the sample stimuli on probe trials. With a change in the baseline contingencies to T1→Y2 and H1→B2, the pigeons should now match nonidentical form stimuli to each other on BB probe trials (i.e., T1→H2 and H1→T2).

Second, Experiment 2 provided an additional probe-trial assessment for the two Group C pigeons that responded more frequently to the matching form stimuli in Experiment 1. As controls for Group R, they, too, were given the BC task reversal and then re-tested. If the Group C pigeons were ignoring the ordinal position of the stimuli or demonstrating an identity bias, they should continue to respond to the physically identical sample-comparison combinations on a second set of BB probe trials. Next, they were retrained with the AC task now included prior to testing for reflexivity one final time. If the baseline contingencies controlled their responding, then they should match nonidentical form stimuli to one another in this last test—the same prediction as for the Group R pigeons. If, instead, they were exhibiting an identity bias, then they should continue to respond more frequently on the matching form-form BB probe trials.
EXPERIMENT 2

Urcuioli’s (2008) theory predicts that the baseline reinforcement contingencies determine which stimuli become class members. If the contingencies arrange that responding to a triangle comparison (T2) after a red sample (R1), a blue comparison (B2) after a triangle sample (T1), and a blue comparison (B2) after a red sample (R1) are reinforced, then the resulting stimulus class will be [R1, T2, T1, B2]. If, however, one of those contingencies were changed—e.g., responding to a blue comparison (B2) after a horizontal sample (H1) is now reinforced—then the class membership should change to [R1, T2, H1, B2]. Consequently, BB (form-form) probe trials should yield higher comparison response rates on nonmatching trials (e.g., H1 $\rightarrow$ T2).

There is a precedent for changing a baseline relation to determine the effect of the new reinforcement contingencies on existing stimulus class members (e.g., Campos et al., 2014; Dube, McIlvane, Callahan, & Stoddard, 1993; Pilgrim & Galizio, 1990; Vaughan, 1988). For example, Campos, Urcuioli, and Swisher (2014) demonstrated an instance in which a baseline reversal (i.e., change in contingencies) resulted in evidence for class rearrangement. Pigeons initially received training on AB hue-form, AA’ hue oddity, and BB’ form oddity matching that presumably yielded two 4-member
classes: [R1, G2, H1, T2] and [G1, R2, T1, H2]. Consistent with this, pigeons demonstrated BA form-hue symmetry: Specifically, they matched a triangle sample (T1) to a red comparison (R2) and a horizontal sample (H1) to a green comparison (G2) after having been trained to do the reverse (i.e., R1→T2 and G1→H2). Later, pigeons were retrained on AB hue-form, AA hue identity, and BB' form oddity, which presumably yielded the following reorganized 4-member classes: [R1, R2, H1, T2] and [G1, G2, T1, H2]. They received BA symmetry testing again but this time demonstrated BA' anti-symmetry: Pigeons now matched a horizontal sample (H1) to a red comparison (R2) and a triangle sample (T1) to a green comparison (G2).

Changing the contingencies for one baseline task here should also result in evidence for class rearrangement. The Group R pigeons originally acquired AB, BC, and AC matching (see top of Table 1) but were now retrained with new contingencies on their BC (form-hue) matching task (see Table 2): Responding to a yellow comparison (Y2) after a triangle sample (T1) and responding to a blue comparison (B2) after a horizontal sample (H1) was reinforced. After retraining, the reorganized stimulus classes should be [R1, T2, H1, B2] and [G1, H2, T1, Y2] as shown in Figure 8. When tested again for an emergent BB relation (see far right column of Table 2), these pigeons should now match a horizontal comparison (H2) to a triangle sample (T1) and a triangle comparison (T2) to a horizontal sample (H1)—the opposite of what they demonstrated in Experiment 1.
Pigeons C2 and C3 received the same change in their BC baseline relations (see bottom of Table 2). Their stimulus classes should now be [R1, T2], [T1, Y2], [G1, H2], and [H1, B2]. Again, there are no common elements across classes and no possible class merger. If their previous performances on BB (form-form) test trials are either evidence for ignoring ordinal position or for an identity bias, then test performances after changing baseline contingencies should be unaffected.

After these tests, Pigeons C2 and C3 were retrained with the arbitrary AC hue-hue relation added to their AB and BC' tasks. As for Group R, the AC contingencies arranged that matching a blue comparison (B2) to a red sample (R1) and a yellow comparison (Y2) to a green sample (G1) were reinforced. Adding this baseline task should create two new stimulus classes with elements common to the other classes and, thus, class merger. The resulting 4-member stimulus classes of [R1, T2, H1, B2] and [G1, H2, T1, Y2] predict the same “anti-reflexivity” effect predicted for Group R.

Method

Subjects

The same subjects, except for C1 and C4, as in Experiment 1 participated.

Apparatus

The apparatuses were the same as in Experiment 1.
Procedure

**Successive matching re-acquisition 1.** Pigeons in Group R simultaneously acquired AB hue-form, BC’ form-hue, and AC symbolic matching tasks. The AB hue-form and AC symbolic tasks were the same as in Experiment 1, but the BC form-hue task changed (see top of Table 2). That is, pigeons now matched a yellow comparison (Y2) to a triangle sample (T1) and a blue comparison (B2) to a horizontal sample (H1). Pigeons C2 and C3 simultaneously acquired AB hue-form and BC’ form-hue matching tasks with the same change in the BC form-hue contingencies (see the bottom of Table 2).

All pigeons had to meet criterion (DRs at or above .80 for all of their tasks for five of six consecutive sessions) followed by a minimum of 10 overtraining sessions. Once each pigeon had completed their overtraining sessions at criterion, BB (form-form) probe testing began.

**Successive matching testing 1.** This consisted of eight BB (form-form) test sessions with triangle and horizontal sample and comparison stimuli. As before, test sessions occurred in successive pairs of two separated by at least five baseline sessions at criterion. All probe trials were nonreinforced and all other procedural details were identical to those described for Groups R and C in Experiment 1.

**Successive matching re-acquisition 2.** After their eight BB reflexivity tests following just AB and BC’ training, C2 and C3 received training with the AC relations added to AB and BC’ successive matching. The contingencies for
all three tasks were the same as for Group R (see top of Table 2). Group R did not receive any further training during this time.

**Successive matching testing 2.** This again consisted of eight BB reflexivity tests. Group R pigeons received eight additional test sessions after their initial eight (for a total of 16 test sessions) to detect any possible delayed emergence effects (Sidman, Kirk, & Willson-Morris, 1985). Group C pigeons received eight BB tests which now included all three baseline relations. All other procedural details were the same as previously described.

**Results and Discussion**

**Acquisition and Baseline Performance**

All eight pigeons met criterion on all of their tasks. Group R pigeons met criterion in 2.2 sessions on the AB hue-form task, 30.5 sessions on the BC’ form-hue task, and 11.8 sessions on the AC symbolic task. This difference was statistically significant, $F(2, 10) = 8.39$, and was obviously due to the change in contingencies on the BC (form-hue) task from Experiment 1, which resulted in the pigeons having to learn the new contingencies. Group C pigeons met criterion with two tasks in 1.0 and 28.0 sessions on the AB (hue-form) and BC’ (form-hue) tasks, respectively. They, too, took longer to acquire the reversed BC relations. Later, when trained on three baseline tasks, they met criterion in 9.5, 17.0, and 16.5 sessions on the AB (hue-form), BC’ (form-hue), and AC (symbolic) tasks, respectively.

Figure 9 shows the re-acquisition data for Group R on the AB hue-form (open circles), AC symbolic hue-hue (open squares), and BC’ form-hue (open
triangles) tasks. The pigeons had experience with the AB relation from Experiment 1, so performance on that task for all of the birds started above .80 and remained above .80 for all sessions. Performance on the AC (hue-hue) task was also disrupted when the BC (form-hue) baseline changed, but it quickly recovered.

Figure 10 shows the re-acquisition data for the control pigeons. C2 and C3 (left side of the figure) had a change in their BC (form-hue) task contingencies, which disrupted BC’ performance and took them longer to meet criterion relative to their AB (hue-form) task for which the contingencies remained the same. They later received training on the AC (symbolic) relation (right side of the figure). Both pigeons show roughly the same pattern of acquisition: Performance on the AB hue-form task was better than that on the AC (symbolic) and BC’ (form-hue) tasks.

The DRs for the Group R pigeons for the last five sessions in overtraining prior to the first set of eight reflexivity tests were .94 for the AB (hue-form) task, .89 for the BC’ (form-hue) task, and .93 for the AC (symbolic) task. This difference was statistically different, $F(2, 10) = 8.39$, and was due to slightly lower accuracy on the BC (form-hue) task than the other two tasks. The DRs for Pigeons C2 and C3 for the last five sessions in overtraining with two baselines were .93 and .94 for the AB (hue-form) task and .91 and .93 for the BC’ (form-hue) tasks, respectively, which did not differ. The DRs for C2 and C3 for the last five sessions in overtraining with three baselines were .97 and .91 for the AB, .95 and .92 for the BC’, and .95 and .93 for the AC tasks,
respectively. Pigeon C2’s DRs were slightly higher than C3’s DRs, but they were both well above the .80 criterion for each of the tasks.

Most of the DRs on the test sessions were at or above .80. Only 23 instances out of 368 fell below .80. Most of those were in the .71-.79 range, with one at .68.

**Test Performance 1**

Figures 11 and 12 show the comparison pecks per second for the reflexivity tests for Groups R and C, respectively, on the AB (hue-form) baseline (open circles) and nonreinforced BB (form-form) probe (filled circles) trials. For comparison, the test performances from Experiment 1 (“Test 1”) are shown in the left column of both graphs for all pigeons. As before, all pigeons responded more frequently to the comparison stimuli on the reinforced baseline trials than to the comparison stimuli on the nonreinforced baseline trials during testing.

None of the Group R pigeons responded more frequently to the nonmatching comparison stimulus on BB form probe trials than to the matching comparison stimulus on their eight tests after the BC reversal (“Test 2” in Figure 11). In fact, three (R1, R4, and R6) pigeons responded significantly more frequently to the matching comparison stimulus than to the nonmatching comparison stimulus on probe trials, $F_{s}(1, 62) = 5.93, 12.44, \text{ and } 8.97$, respectively. The remaining three (R2, R3, and R5) pigeons responded nondifferentially to the comparison stimuli on the “Test 2” probes, $F_{s}(1, 62) < 3.38$. 
One of the two Control group pigeons (C3) responded nondifferentially on BB form probe trials, $F(1, 62) = 3.72$ (see Figure 12). The other Control group pigeon (C2) continued to respond more frequently to the matching sample-comparison combinations on probe trials than to the nonmatching sample-comparison combinations, $F(1, 62) = 4.24$.

**Test Performance 2**

This 8-session test was a continuation of the prior eight tests for Group R. None of the Group R pigeons responded more frequently to the nonmatching comparison stimulus on BB form probe trials than to the matching comparison stimulus on their additional set of eight tests (“Test 2 continued” in Figure 11) after the BC reversal. In fact, R4 and R5 responded significantly more frequently to the matching comparison stimulus than to the nonmatching comparison stimulus on probe trials, $F_s(1, 62) = 25.07$ and 13.41, respectively. The remaining four (R1, R2, R3, and R6) pigeons responded nondifferentially to the comparison stimuli on the matching and nonmatching reflexivity probes, $F_s(1, 62) < 1.86$. Neither of the two Control group pigeons (C2 and C3) responded differentially on BB form probe trials after the AC baseline task was added to the AB and BC’ tasks, $F_s(1, 62) = 0.04$ and 3.01, respectively.

In this experiment, there was no evidence that the classes for the Group R pigeons were rearranged from [R1, T2, T1, B2] and [G1, H2, H1, Y2] to [R1, T2, $H_1$, B2] and [G1, H2, $T_1$, Y2] with the training of the reversed $T_1\rightarrow Y_2$ and $H_1\rightarrow B_2$ relations. In fact, some Group R pigeons continued to respond differentially in accord with their original contingencies on the BB’ probe trials.
despite their reversed BC (form-hue) contingencies. The nondifferential probe-
trial response patterns for Pigeons R2, R3, and R5 on “Test 2” and Pigeons
R1, R2, and R3 on “Test 2 continued” was probably not due to extinction given
that they were still responding at relatively high rates on BB probe trials. It is
more likely due to the change in contingencies. Stated otherwise, had their
classes remained the same, they should have continued to demonstrate
reflexivity like R4 and R6.

Campos, Urcuioli, and Swisher (2014) found evidence for class
membership rearrangement on symmetry probes, but this was not the case on
the present reflexivity probes. The relation that was reversed in Campos et al.
(2014) was either hue oddity to hue identity or form oddity to form identity; thus,
the sample and comparison stimuli either physically matched one another or
were the opposite in those trials. The tested relation was arbitrary in which the
sample and comparison stimuli did not physically match one another. The
relation reversed in the present experiment was an arbitrary relation, and the
stimuli in the probe trials either physically matched one another or did not
physically match one another. This might be an important difference that
contributed to present findings, although Urcuioli’s (2008) theory predicts that it
should not matter.

Pigeon C2 responded like Pigeons R4 and R6 on its “Test 2” probe trials
by continuing to match identical form stimuli to one another. However, in “Test
3” after the third, AC (hue-hue) baseline relation was added to their two other
baseline tasks, C2 and C3 responded nondifferentially on the BB probe trials.
Although it can be very difficult for pigeons to learn baseline reversals (e.g., Jitsumori, Siemann, Lehr, & Delius, 2002), the change in the baseline contingencies here did not present a problem for either pigeon. Perhaps with continued training and testing, both groups of pigeons would have eventually demonstrated the predicted anti-reflexivity effects.

The baseline contingencies for C2 and C3 seemed to contribute little to their probe-trial performances, so it is more likely that they were showing an identity bias. The fact that they performed on probe trials similarly to the majority of the Group R birds until they received their third task suggests an identity bias operated for them.

Experiment 3 was designed to further investigate the mechanism underlying reflexive-like responding for these pigeons. If such responding arose because they were ignoring the ordinal position of stimuli on AB and BC tasks, they should also show BA symmetry. On the other hand, if their performances reflected an identity bias, they should not demonstrate symmetry.
EXPERIMENT 3

These two pigeons (C2 and C3) next received BA form-hue symmetry tests to determine in part what produced their differential performance on reflexivity probes in Experiment 1. There are two alternatives for why these pigeons matched a triangle comparison (T2) to a triangle sample (T1) and a horizontal comparison (H2) to a horizontal sample (H1): 1) they were showing evidence for an identity bias or 2) they formed classes of stimuli that did not involve ordinal position—e.g., [R, T] and [G, H]. Nothing in their training should permit them to demonstrate symmetry according to Urcuioli’s (2008) theory. Given that these pigeons matched each form training stimulus to itself (Sidman & Tailby, 1982), then perhaps these pigeons’ behavior does not correspond to those theoretical assumptions and, thus, would also show evidence for symmetry—matching former samples from training to former comparisons. Humans with a history of reinforced AB matching are able, without further training, to demonstrate BA symmetry (Pilgrim & Galizio, 1990; Sidman & Tailby, 1982; Travis, Fields, & Arntzen, 2014).

If, for some unknown reason, C2 and C3 were ignoring the ordinal position of the stimuli in Experiment 1, then they should pass probe-trial tests for symmetry by responding more frequently to a red comparison after a
triangle sample and to a green comparison after a horizontal sample (i.e., the reverse of the hue-form sample-comparison relations on which they were trained). Alternatively, if they do not pass tests for symmetry, then their responding on the reflexivity probe trials in Experiment 1 more likely reflects an identity bias.

**Method**

**Subjects**

Pigeons C2 and C3 from Experiment 2 participated.

**Apparatus**

The apparatuses were the same as in Experiment 1.

**Procedure**

**Successive matching acquisition.** Pigeons C2 and C3 retained their AB (hue-form), BC’ (form-hue), and AC (symbolic) matching baseline relations (see the top of Table 2). They continued to match a yellow comparison (Y2) to a triangle sample (T1) and a blue comparison (B2) to a horizontal sample (H1) along with their other two baseline relations. Both pigeons had to meet criterion (DRs at or above .80 for all of their tasks for five of six consecutive sessions) prior to BA symmetry testing.

**Successive matching testing.** The pigeons were then given eight BA (form-hue) symmetry tests with the triangle and horizontal sample and red and green comparison stimuli. Test sessions occurred in successive pairs of two separated by at least five baseline sessions at criterion levels of performance. All probe trials were nonreinforced.
Results and Discussion

Baseline Performance

The pigeons quickly met criterion again on their AB, BC’, and AC matching tasks. Prior to testing, average DRs on the three baseline tasks were .97 and .97 on the AB task, .95 and .99 on the BC’ task, and .97 and .95 on the AC task for C2 and C3, respectively. During testing, there were only two (.75 and .76) instances out of 48 in which the DRs fell below .80, and they both were the BC’ (form-hue) discrimination for pigeon C2.

Test Performance

Figure 13 shows the comparison pecks per second for the symmetry tests for pigeons C2 and C3 on the AB (hue-form) baseline (open circles) and nonreinforced BA (form-hue) probe (filled circles) trials. Both continued to respond more to the comparison stimuli on reinforced AB baseline trials than to the comparison stimuli on nonreinforced AB baseline trials.

More importantly, neither pigeon responded differentially on BA symmetry tests, $F_{s}(1, 62) < 1.25$. Probe-trial rates of responding were nearly identical on matching and nonmatching probes.

Because C2 and C3 showed a reflexivity effect in Experiment 1, they should also show evidence for symmetry if they were ignoring ordinal position. In other words, if their stimulus classes were simply [R, T] and [G, H], then they should have been able to match $T \rightarrow R$ and $H \rightarrow G$ on BA symmetry tests. Their failure to do so indicates that they were probably not ignoring the ordinal position of the stimuli (e.g., [R1, T2] and [G1, H2] does not yield $T1 \rightarrow R2$ and...
H1→G2 matching). Their prior reflexivity-test performances, therefore, seem to be due to an identity bias, not to stimulus class formation.

Although these pigeons matched form stimuli to one another on probe trials in Experiment 1, pigeons C1 and C4 did despite with the same training on AB and BC tasks. According to Urcuioli (2008), if pigeons C1 and C4 had received the AC task as well, they should now match form stimuli to one another. Experiment 4 tested this prediction.
EXPERIMENT 4

In Experiment 1, pigeons C1 and C4 responded nondifferentially on reflexivity probe trials. It is likely that they did not demonstrate reflexivity because they lacked the third baseline which provides the common elements to merge the remaining stimulus classes (Urcuioli, 2008). If so, then providing that third, AC task should permit these pigeons to demonstrate reflexivity.

The third, AC baseline task (cf. Group R in Experiment 1) involved the reinforced symbolic R1→B2 and G1→Y2 relations. The three baseline relations would now be the same as those for Group R from Experiment 1 (cf. top of Table 1). With the addition of classes [R1, B2] and [G1, Y2], the six 2-member classes should merge into classes [R1, T2, T1, B2] and [G1, H2, H1, Y2] as shown in Figure 2. Thus, they might now show evidence for T1→T2 and H1→H2 matching (reflexivity) on probe trials.

Method

Subjects

Pigeons C1 and C4 from Experiment 1 participated.

Apparatus

The apparatuses were the same as in Experiment 1.
Procedure

**Successive matching acquisition.** Pigeons C1 and C4 were concurrently trained on AB (hue-form), BC (form-hue), and AC (symbolic) matching tasks (see top of Table 1). The addition of the AC symbolic matching task in which they matched a blue comparison (B2) to a red sample (R1) and a yellow comparison (Y2) to a green sample (G1) meant that each session now contained 96 acquisition trials, 32 with each task.

Both pigeons had to meet criterion (DRs at or above .80 for all of their tasks for five of six consecutive sessions) followed by a minimum of 10 overtraining sessions. Once they had completed their overtraining sessions at criterion, BB (form-form) probe tests began.

**Successive matching testing.** This consisted of eight BB (form-form) tests with triangle and horizontal sample and comparison stimuli conducted as successive pairs of two test sessions separated by at least five baseline sessions at criterion. As before, all probe trials were nonreinforced.

Results and Discussion

**Acquisition and Baseline Performance**

Figure 14 shows the acquisition data for pigeons C1 and C4 on the AB hue-form (open circles), AC symbolic hue-hue (open squares), and BC form-hue (open triangles) tasks. Adding the AC task disrupted performance on the BC task but not the AB task. Both pigeons eventually met criterion on all of their tasks. C1 and C4 reached criterion in 1.0 and 4.0 sessions on the AB hue-form task, 55.0 and 9.0 sessions on the BC form-hue task, and 21.0 and
11.0 sessions on the added AC symbolic task, respectively. The DRs for C1 and C4 for the last five sessions in overtraining were .93 and .93 for the AB (hue-form), .87 and .94 for the BC (form-hue), and .91 and .92 for the AC (symbolic) tasks, respectively.

Most of the DRs on test sessions were at or above .80. Only in eight instances out of 48 did the DRs fall below .80. Most of those were in the .71-.79 range. One fell below that (.65). All of the DRs below .80 belonged to C1 (three on the AC task and five on the BC task).

**Test Performance**

Figure 15 shows the comparison pecks per second for the reflexivity test ("Test 2") for the two pigeons on the AB (hue-form) baseline (open circles) and nonreinforced BB (form-form) probe (filled circles) trials. For comparison, the test performances ("Test 1") from Experiment 1 are shown in the left column. As before, both pigeons continued to respond more frequently to the comparison stimuli on the reinforced baseline trials than on nonreinforced baseline trials. Unlike Experiment 1, pigeons C1 and C4 now responded significantly more frequently to the matching comparison stimulus than to the nonmatching comparison stimulus on the BB form probe trials, $F$s(1, 62) = 7.19 and 25.46, respectively ("Test 2" in Figure 15).

Thus, adding the AC (symbolic) baseline relations to the other two baseline tasks (AB and BC) yielded evidence for reflexivity. Theoretically, adding the reinforced baseline relations $R1 \rightarrow B2$ and $G1 \rightarrow Y2$ from AC matching resulted in two new stimulus classes, $[R1, B2]$ and $[G1, Y2]$, which should in
turn merge the remaining classes into the two 4-member classes: [R1, T2, T1, B2] and [G1, H2, H1, Y2]. In Experiment 1, they presumably formed only four 2-member classes (see Figure 3) neither of which contained a triangle sample and comparison or a horizontal sample and comparison. According to Urcuioli’s (2008) theory, they needed the common elements supplied by the AC task for class merger and in order to demonstrate reflexivity.
EXPERIMENT 5

Experiment 2 was unsuccessful in demonstrating anti-reflexivity with BC training relations that were the reverse of those used in Experiment 1. The Group R and C pigeons in that experiment were experienced birds that previously demonstrated reflexivity, and there may have been some carryover from Experiment 1 into Experiment 2. Anti-reflexivity required a rearrangement of the stimulus classes hypothesized to underlie those earlier (reflexivity) performances. The next experiment asked whether anti-reflexivity would be more likely if class rearrangement were not required. In other words, would pigeons without prior baseline training be more likely to demonstrate anti-reflexivity on BB probe trials?

Oddity (or "difference") is the opposite of the similarity-based concept of identity (e.g., Berryman, Cumming, Cohen, & Johnson, 1965; Bundy, Mackintosh, & Boakes, 1985). Rather than responding preferentially or more frequently to the comparison stimulus that physically matches the sample, oddity involves more frequent responding to the comparison stimulus that does not physically match the sample (e.g., Campos, Urcuioli, & Swisher, 2014; Carter & Werner, 1978; Lipsitt & Serunian, 1963; Urcuioli, 1977).
While there have been many demonstrations of oddity (also known as oddity-from-sample) and same/different performances (Castro, Wasserman, & Young, 2012; Cook, Kelly, & Katz, 2003; Zentall & Hogan, 1974; Zentall, Hogan, & Edwards, 1980; Zentall, Hogan, Edwards, & Hearst, 1980; Zentall & Hogan, 1974; Zentall, Hogan, & Holder, 1974), some results indicate, and some authors assert, that pigeons do not solve these tasks relationally (e.g., Berryman, Cumming, Cohen, & Johnson, 1965; D'Amato, Salmon, & Colombo, 1985; Wilson, Mackintosh, & Boakes, 1985). Thus, as it is important to investigate the origins of identity relational responding, it is equally as important to investigate the origins of oddity relational responding. Accordingly, identity and oddity have as their correlates reflexivity and anti-reflexivity, respectively, the latter referring to emergent effects that are independent of a history of reinforced identity and oddity responding. Importantly, Urcuioli's (2008) theory predicts an emergent relation for nonmatching stimuli (cf. Sweeney & Urcuioli, 2010) in addition to an emergent relation between matching stimuli. Specifically, anti-reflexivity (or emergent oddity) should also arise solely from training a set of arbitrary matching relations.

Sweeney and Urcuioli (2010) trained one group of pigeons on AB (hue-form) arbitrary matching, BA (form-hue) arbitrary matching, and BB' (form-form) oddity. Four of five pigeons later responded more frequently to the nonmatching hue sample-hue comparison (AA) probe-trial combinations, but none of these anti-reflexivity differences were significant. After 10 additional tests, one of five pigeons responded significantly more frequently to the green
comparison after the red sample and to the red comparison after the green sample than to the matching hue-hue combinations.

This very limited demonstration of responding to the odd comparison stimulus on hue-hue probe trials could be evidence for either anti-reflexivity or generalized oddity because baseline training involved reinforced, BB’ form-form oddity. To demonstrate anti-reflexivity, baseline training must involve all arbitrary matching tasks. In the present study, then, Group O (Oddity) pigeons were trained on three arbitrary matching tasks (see top of Table 2): AB (hue-form), BC (form-hue), and AC (hue-hue) matching structured in such a way that, in testing, pigeons should respond more to the nonmatching form comparisons than to the matching ones on BB probe trials (Urcuioli, 2008). Figure 8 shows the theoretical derivation.

A control group of pigeons (Group A – anti-reflexivity control) received only AB and BC baseline training. The hypothesized stimulus classes for this group are similar to the classes shown in Figure 3 (except the bottom row of classes are [H1, B2] and [T1, Y2]). Clearly, these provide no basis for emergent form-form (BB) responding: The control pigeons should respond nondifferentially on BB form-form probe trials.

Method

Subjects

Ten White Carneau pigeons obtained from Double “T” Farms (Glenwood, IA) participated in the study. They were all experimentally naïve and were given free access to food (Purina Pro11 mixed grain), water, and grit
upon arrival to the laboratory. It took 12-34 days for the pigeons to reach a stable, free-feeding weight, after which each was reduced to 80% of its free-feeding weight prior to their participation. Housing and feeding regimens were the same as in Experiment 1. Prior to their experimental participation, they were randomly assigned to two groups (O and A – see Table 2). One Group A control pigeon died.

**Apparatus**

The apparatuses were the same as in Experiment 1. Approximately one half of the pigeons in each group were run in each experimental chamber.

**Procedure**

**Preliminary training.** All preliminary training was the same as in Experiment 1.

**Successive matching acquisition.** Pigeons in Group O simultaneously acquired AB (hue-form), BC (form-hue), and AC (symbolic hue-hue) matching tasks (see top of Table 2). These were the same as those for Group R in Experiment 2. Pigeons in Group A simultaneously acquired AB (hue-form) and BC (form-hue) matching tasks, identical to those for Group C in Experiment 2 (see bottom of Table 2). After each pigeon met criterion (i.e., DRs at or above .80 for all of their tasks for five of six consecutive sessions), they received a minimum of 10 overtraining sessions which ended when criterion performance was again met.

**Successive matching testing.** All pigeons received eight BB (form-form) tests with triangle and horizontal sample and comparison stimuli. Test
sessions occurred in successive pairs of two separated by at least five baseline sessions—pigeons were required to meet criterion again in between each set of two test sessions. All probe trials were nonreinforced.

Results and Discussion

Acquisition and Baseline Performance

All pigeons met criterion on their respective tasks. Group O pigeons met criterion in 52.0 sessions on the AB (hue-form) task, 40.2 sessions on the BC (form-hue) task, and 27.2 sessions on the AC (symbolic) task. This difference was not statistically significant, $F(2, 12) = 0.17$. Group A pigeons met criterion in 27.0 and 56.3 sessions on the AB (hue-form) and BC (form-hue) tasks, respectively. These differences were not statistically significant, $F(1, 6) = 3.04$. Figures 16 and 17 present the individual acquisition results for Groups O and A, respectively.

DRs for the Group O pigeons over the last five sessions in overtraining preceding the first anti-reflexivity tests were .87 for the AB (hue-form) task, .89 for the BC (form-hue) task, and .91 for the AC (symbolic) task. This difference was not statistically different, $F(2, 12) = 2.26$. DRs for the Group A pigeons over the last five sessions in overtraining were .92 and .89 for the AB (hue-form) and BC (form-hue) tasks, respectively. This was not a statistically significant difference, $F(1, 6) = 0.90$.

Most of the DRs during the test sessions were at or above .80. Only in 14 instances out of 184 did the DRs fall below .80. All but three were in the .72-.79 range.
Test Performance

Figures 18 and 19 show the comparison pecks per second for Groups O and A, respectively, on the AB hue-form baseline (open circles) and nonreinforced BB form-form probe (filled circles) trials. As expected, every pigeon responded more frequently to the comparison stimuli on the reinforced baseline trials than to the comparison stimuli on the nonreinforced baseline trials.

More importantly, on the BB probe-test trials, three Group O pigeons (O1, O3, and O5) responded more frequently to the nonmatching comparison stimulus than to the matching comparison stimulus. For two pigeons, O1 and O3, the difference was statistically significant, $F_s(1, 62) = 4.59$ and $7.66$, respectively. The difference for pigeon O5 was not, $F(1, 62) = 2.94$. The remaining two Group O pigeons (viz., O2 and O4) responded nondifferentially to the comparison stimuli on all trials, $F_s(1, 62) < 0.77$.

Three of the four (i.e., A2, A3, and A4) Group A control pigeons responded nondifferentially on BB (form-form) probe trials, $F_s(1, 62) = 1.32$, 1.19, and 0.42, respectively. Surprisingly, the remaining Control group pigeon (A1) responded more frequently to the nonmatching sample-comparison combinations than to the matching sample-comparison combinations on the probe trials, $F(1, 62) = 9.55$. This result was statistically significant.

Two Group O pigeons demonstrated evidence for anti-reflexivity by matching a triangle comparison (T2) to a horizontal sample (H1) and a horizontal comparison (H2) to a triangle sample (T1) on probe trials, as
predicted from their hypothesized 4-member stimulus classes – [R1, T2, H1, B2] and [G1, H2, T1, Y2]. Evidently, Urcuioli’s (2008) theoretical assumption that the stimulus classes are based on the reinforcement contingency is correct, and pigeons can not only show evidence for emergent reflexivity but also for emergent anti-reflexivity.

Most of the pigeons in control Group A did exactly what was predicted: They responded equally often on matching and nonmatching probe trials. Their baseline training tasks did not include potentially overlapping stimuli across classes which could yield nonmatching form stimuli in the same class.

Pigeon A1, however, did respond differentially on the BB probes: It responded more frequently to a horizontal comparison after a triangle sample and to a triangle comparison after a horizontal sample. Its data are surprising both from a theoretical viewpoint and in view of 1) the apparent identity biases shown by some of the control pigeons in Experiment 1, and 2) Sweeney and Urcuioli’s (2010) difficulty obtaining anti-reflexivity after training pigeons on form oddity matching in baseline.

It has been suggested (e.g., Carter & Werner, 1978, p. 571; Zentall, Edwards, Moore, & Hogan, 1981, p. 77 & 81) that pigeons might be biased toward pecking a comparison stimulus that does not match the sample stimulus in matching procedures because pecking the preceding sample stimulus is never reinforced. For example, pigeons sometimes show higher initial accuracy on oddity than on identity two-alternative MTS tasks in training (e.g., Berryman, Cumming, Cohen, & Johnson, 1965). If the pigeon learns that
pecking a stimulus (like a sample) is not reinforced, it may be biased to respond to a subsequent (e.g., comparison) stimulus that differs from it. With extensive training, this effect should presumably dissipate, but perhaps it resurfaces on a new trial type like the few BB reflexivity probe trials encountered in test sessions. However, this account does not explain why there were two pigeons in Experiment 1 that demonstrated an *identity* bias on reflexivity probe trials.
EXPERIMENT 6

In Experiment 2, none of the pigeons showed evidence for stimulus class rearrangement after reversing the reinforced relations in one (i.e., BC form-hue) task. Other results (e.g., Campos et al., 2014; Group R in Experiment 1, Group C in Experiment 4, and Group O in Experiment 5) indicate that the baseline contingencies are responsible for the emergence of reflexivity and anti-reflexivity and that the stimulus classes should be malleable enough to reorganize with a corresponding change in a baseline relation. The purpose of this experiment was to determine if 1) changing one task would now yield reflexivity for the Group O pigeons, and 2) adding the third task would yield anti-reflexivity for the Group A pigeons that did not show this effect in Experiment 5.

For the Group O pigeons, their original AB (hue-form) and AC (symbolic) relations were maintained but their BC (form-hue) relations were reversed. Specifically, these pigeons now received food for matching a yellow comparison (Y2) to a horizontal sample (H1) and a blue comparison (B2) to a triangle sample (T1). Theoretically, their two 4-member stimulus classes should change to those shown in Figure 2, yielding BB reflexivity in subsequent testing.
For Group A, pigeons now received training on a new AC symbolic task in addition to their AB (hue-form) and BC (form-hue) tasks. Adding the AC symbolic relations should theoretically result in the two 4-member classes shown at the bottom of Figure 8. Consequently, they should now show anti-reflexivity: responding more frequently to a triangle comparison (T2) after a horizontal sample (H1) and to a horizontal comparison (H2) after a triangle sample (T1) on probe trials. Although Pigeon A1 was already showing this pattern of results, the difference in responding might become more pronounced with the addition of the AC symbolic task.

Method

Subjects

The same subjects as in Experiment 5 participated.

Apparatus

The apparatuses were the same as in Experiment 1.

Procedure

Successive matching acquisition. Pigeons in Group O continued training on their original AB (hue-form) and AC (hue-hue) matching tasks, but their BC (form-hue) matching task was reversed (see top of Table 1). That is, pigeons now matched a blue comparison (B2) to a triangle sample (T1) and yellow comparison (Y2) to a horizontal sample (H1).

Pigeons in Group A continued their original training on AB (hue-form) and BC (form-hue) matching tasks but, now, the AC (symbolic) matching task was added (see top of Table 2). Specifically, they matched a blue comparison
(B2) to a red sample (R1) and a yellow comparison (Y2) to a green sample (G1).

After each pigeon met criterion (i.e., DRs at or above .80 for all of their tasks for five of six consecutive sessions), they completed a minimum of 10 overtraining sessions to criterion, after which BB (form-form) testing began.

**Successive matching testing.** All pigeons received eight BB (form-form) tests with triangle and horizontal sample and comparison stimuli. Test sessions occurred in successive pairs of two separated by at least five baseline sessions at criterion levels. All probe trials were nonreinforced.

**Results and Discussion**

**Acquisition and Baseline Performance**

All nine pigeons met criterion on all three of their tasks. Group O met criterion in an average of 5.6 sessions on the AB (hue-form) task, 33.8 sessions on the reversed BC (form-hue) task, and 20.2 sessions on the AC (symbolic) task. This difference was statistically significant, $F(2, 12) = 7.23$, and it was largely due to the difference between the rapid re-acquisition of the AB task versus the acquisition of the reversed contingencies on the BC task. Group A pigeons met criterion in 1.0, 4.5, and 7.3 sessions on the AB (hue-form), BC (form-hue), and AC (symbolic) tasks, respectively. These differences were statistically significant, $F(2, 9) = 12.73$, and they were due primarily to learning the new, added AC task.

Figure 20 shows the acquisition data for Group O on the AB hue-form (open circles), AC hue-hue (open squares), and BC form-hue (open triangles)
tasks. Changing the BC task initially disrupted performance on the AC task but not the AB task.

Figure 21 shows the acquisition data for the Group A pigeons. All four pigeons performed better on their already learned AB (hue-form) and BC (form-hue) tasks than on the new AC (hue-hue) task.

The DRs for the Group O pigeons over the last five sessions in overtraining were .93 for the AB, .89 for the BC', and .92 for the AC tasks. This difference was not statistically different, $F(2, 12) = 3.21$. The discrimination ratios for the Group A pigeons for the last five sessions in overtraining were .92, .94, and .93 for the AB, BC, and AC matching tasks, respectively. This was not a statistically significant difference, $F(1, 6) = 0.26$.

Most of the DRs on test sessions were at or above .80. In only six instances out of 216 did the DRs fall below .80. Most of those were in the .70-.79 range. Two fell below that (.60 and .64).

**Test Performance**

Figures 22 and 23 show the comparison pecks per second for Groups O and A, respectively, on the AB hue-form baseline (open circles) and nonreinforced BB form-form probe (filled circles) trials. Every pigeon responded more frequently to the comparison stimuli on reinforced baseline trials than to the comparison stimuli on nonreinforced baseline trials.

On the BB probe trials (right column), all five Group O pigeons now responded more frequently to matching comparison stimuli than to nonmatching comparison stimuli. For three of those pigeons (i.e., O1, O4, and
O5), the difference was statistically significant, $F_s(1, 62) = 17.45$, 5.76, and 22.91, respectively. The differences for pigeons O2 and O3 were not, $F_s(1, 62) < 3.46$.

Three of the four Group A pigeons (A1, A2, and A3) responded more frequently to the nonmatching comparison stimulus on probe trials than to the matching comparison stimulus. For two of these pigeons (A1 and A2), the difference was statistically significant, $F_s(1, 62) = 11.21$ and 10.14, respectively. It was not statistically significant for A3, $F(1, 62) = 1.51$. Pigeon A4 responded nondifferentially on probe trials, $F(1, 62) = 1.27$. Pigeon A1 in Experiment 5 was already responding differentially on BB probe trials, but the difference between rates of responding on nonmatching sample-comparison probes and matching sample-comparison probes became more pronounced after adding the third, AC symbolic baseline relation. In Experiment 5, the comparison response rate difference was .91 versus 1.05 in the present experiment.

Unlike the results of Experiment 2, when the BC (form-hue) relations were reversed and the pigeons were tested for the emergence of anti-reflexivity, some of the Group O pigeons showed evidence consistent with rearrangement of stimulus classes. Rather than continuing to respond relatively more frequently to a horizontal comparison (H2) after a triangle sample (T1) and to a triangle comparison (T2) after a horizontal sample (H1)—indicative of the formation of [R1, T2, H1, B2] and [G1, H2, T1, Y2] classes, these pigeons now responded more frequently to a triangle comparison (T2)
after a triangle sample (T1) and to a horizontal comparison (H2) after a horizontal sample (H1) on reflexivity probes—indicative of the formation of [R1, T2, T1, B2] and [G1, H2, H1, Y2] classes.

Of the pigeons in Group A that did not show evidence of an emergent effect in Experiment 5 after training on just two baseline tasks, one now showed evidence for anti-reflexivity after a third baseline task was added to the other two. With only two baseline relations, the hypothesized stimulus classes were four separate 2-member classes; with three baseline relations, the hypothesized stimulus classes were two 4-member classes (see Figure 8). Training the R1→B2 and G1→Y2 relations provides the necessary [R1, B2] and [G1, Y2] stimulus classes for class merger. Urcuioli’s (2008) theory predicts that with training on the AB, BC, and AC tasks, these pigeons should be able to demonstrate anti-reflexivity.
GENERAL DISCUSSION

In all, 10 of 13 pigeons showed evidence for reflexivity, four of 17 pigeons showed evidence for anti-reflexivity, two of four control pigeons showed identity matching (because the two who were tested did not pass BA symmetry tests in Experiment 3 to indicate that they were ignoring the ordinal position of the training stimuli), and one of the four other control pigeons showed anti-reflexivity (see Table 3). Three of 13 pigeons showed evidence for class reorganization after a BC (form-hue) baseline reversal. Seven of those 13 pigeons did have their performance on reflexivity probes disrupted by the BC reversal but did not show evidence for class reorganization; two continued to show reflexivity with extended testing. Four of eight total control pigeons demonstrated reflexivity or anti-reflexivity when they received their third, AC task which provided common elements for class merger.

Urcuioli’s (2008) theory predicts reflexivity and anti-reflexivity from the three sets of arbitrary baseline relations used here. Simultaneously training AB, BC, and AC arbitrary tasks yields two 4-member classes from which reflexivity (i.e., matching $T1 \rightarrow T2$ and $H1 \rightarrow H2$; see Figure 2) or anti-reflexivity (i.e., matching $T1 \rightarrow H2$ and $H1 \rightarrow T2$; see Figure 8) can be predicted. Changing the BC task should result in class reorganization such that the opposite
emergent relation should be observed (viz., anti-reflexivity instead of reflexivity or vice versa). Pigeons had previously shown evidence for reflexivity that could not be distinguished from generalized identity matching and anti-reflexivity that could not be distinguished from generalized oddity matching in Sweeney and Urcuioli (2010). The present experiments thus provide the first demonstration of those emergent relations that cannot be explained by a prior history of identity or oddity baseline matching.

Some authors have indicated that nonhumans may not be capable of demonstrating evidence for stimulus class formation via emergent relations due to their lack of language and multiple exemplar training (e.g., Dugdale & Lowe, 2000; Hayes, 1989; Horne & Lowe, 1997). The early failures to find symmetry (e.g., Hogan & Zentall, 1977; Sidman et al., 1982) certainly indicated that this might be a fundamental difference between humans and nonhumans. It seemed that, if nonhumans were to demonstrate symmetry, they might need training that more closely resembled typical human experiences. For example, Dugdale and Lowe (2000) reasoned that if any nonhumans should pass tests for symmetry, it would be two chimpanzees that were trained with multiple symmetrical exemplars as a function of their lexigram language system. They also reinforced correct responses on symmetry tests, but neither chimpanzee demonstrated symmetry. This is very compelling evidence that nonhumans would never demonstrate emergent relations like humans. Sidman, however, did not draw a distinction between human and nonhuman equivalence class formation on the basis of language. Rather than equivalence classes being a
byproduct of language, it might be that equivalence class formation is a basic stimulus function (Sidman, 1997, p. 259).

Sidman (2000) and Urcuioli (2008) discuss how stimulus class formation is based on the reinforcement contingency. Previous attempts to find evidence for emergent relations with nonhumans did not correctly specify the functional stimuli. Sidman et al. (1982, p. 43) correctly asserted that they may not have found symmetry with rhesus monkey or baboons because spatial location might have become a controlling variable of the stimuli. Changing the spatial location of those stimuli during symmetry testing then completely changed the functional stimulus and is thus not a valid test for symmetry. They go on to say (p. 43), “Incorrect specification by the experimenter of the controlling stimuli in the conditional discriminations may be the most fundamental factor underlying the absence of symmetry.”

Not only is the spatial location an important part of the functional stimulus, but so, too, is the ordinal position in which stimuli appear. As the spatial location of stimuli does not change in a successive matching procedure, “when” a stimulus is of more concern than “where” a stimulus appears. Pigeons must see the stimuli presented on reflexivity tests as both samples and comparisons prior to probe trials and those stimuli (e.g., T1 and T2 as well as H1 and H2) must participate in the same stimulus class. That is, pigeons would not have responded appropriately if they had not seen the form stimuli as samples (e.g., BC task) or as comparisons (e.g., AB task) prior to reflexivity testing. Additionally, pigeons would not have responded appropriately had the
AC task not been included in baseline training to provide the elements for class merger—the triangle sample and comparison would have remained in separate classes as for pigeons C1 and C4.

If stimulus class formation is in fact due to the reinforcement contingency, properly defining the functional stimulus should provide the necessary conditions for the emergence of new relations. Training two baseline tasks with one common stimulus (e.g., A→B and B→C) is sufficient for seeing emergent relations in testing for humans, but nonhumans require the additional B→B task. Specifically, reinforcement contingencies produce the analytic units from baseline training (i.e., here, the sample and reinforced comparison stimuli) and the equivalence relations (i.e., novel sample-comparison combinations; Sidman, 2000, p. 128). Those properties of the equivalence relation that are tested with humans—reflexivity, symmetry, and transitivity—are all a product of the reinforcement contingency. Language, therefore, is not a necessary condition of stimulus class formation given that nonhumans have demonstrated symmetry (e.g., Campos, Urucioli, & Swisher, 2014; Frank & Wasserman, 2005; Urucioli, 2008) and transitivity (e.g., Urucioli & Swisher, 2015) as well as identity matching (e.g., Sweeney & Urucioli, 2010; Urucioli & Swisher, 2012b). They differ slightly on the requirements for stimulus class formation in humans and nonhumans—nonhumans attend to more than just the nominal property of stimuli and need to acquire additional baseline relations. This is again because pigeons attend to multiple stimulus properties that include ordinal position (e.g., “when” a stimulus appears) and location (e.g., “where” a stimulus appears).
That is not to say that humans do not also attend to ordinal position, but they do not require the same extensive training that pigeons do before demonstrating evidence for stimulus class formation.

If people learned that red and triangle “go together” and that triangle and blue “go together,” they would then be able to select: a red comparison (rather than a green comparison) given a red sample, a triangle comparison (rather than a horizontal comparison) given a triangle sample, a blue comparison (rather than a yellow comparison) given a blue sample (i.e., reflexivity), a red comparison given a triangle sample, a triangle comparison given a blue sample (i.e., symmetry), a red comparison given a blue sample, and a blue comparison given a red sample (i.e., transitivity). With pigeons, they would have to see each stimulus in both sample and comparison positions in baseline in order to demonstrate emergent relations in testing. That is, the experimenter would have to properly define the stimuli in baseline training and emergent relations tests in terms of their ordinal positions as part of the functional stimuli. Which relations they would be able to demonstrate in testing would depend upon the overlapping functional stimuli presented in baseline that promote stimulus class formation.

The Group R pigeons in Experiment 1 demonstrated reflexivity via the reinforcement contingencies involved in training three arbitrary relations, which confirms Urcuioli’s (2008) theoretical predictions about stimulus class formation. None of the control pigeons were expected to show this effect, but two of them did. This was not predicted by Urcuioli’s (2008) theory. However,
it would be predicted by Sidman’s (2000) model if these pigeons were ignoring ordinal position. If they could demonstrate reflexivity like typical human participants, then they should also pass tests for another emergent relation like symmetry (or transitivity). However, these two pigeons did not pass BA symmetry tests in Experiment 3, so their differential responding may simply be due to an uncontrolled identity bias (i.e., without the explicit training of identity relations in baseline).

In Wasserman and Castro (2012), pigeons with experience in three-alternative matching-to-sample showed an advantage for learning fewer “if-then” relations with identity tasks (e.g., matching the comparison of the same rose as the sample rather than to a dog) over “same” category tasks (e.g., matching a daisy to a rose rather than to a dog). Same in this instance does not correspond to identical stimuli but stimuli that belong to a natural or basic category; here, they were both flowers and not animals. These pigeons later continued to select the identical comparison in a two-alternative procedure in which there was no advantage for learning fewer “if-then” relations with identity matching (e.g., selecting the rose in the presence of the rose and not the daisy). However, pigeons learning an equal number of “if-then” relations for identity and “same” category matching did not select the identical comparison more frequently in testing. Adult humans always selected the identical comparison more frequently in testing, perhaps due to their long history of reinforced identity matching. There is nothing apparent in pretraining or successive matching training in the present experiments that would bias
pigeons to be more likely to match identical or nonidentical stimuli. The history of symbolic matching might make it more likely that pigeons would select the nonmatching stimulus, but this does not meet the technical definition for oddity training. That is, the pigeons did not respond away from an identical comparison stimulus in training as is inherent in oddity tasks. The reason for the differential responding on test trials by three (two identity matching and one anti-reflexivity result) of the control pigeons remains unknown.

Sweeney and Urcuioli (2010), Urcuioli (2011), and Urcuioli and Swisher (2012b) also found that most of their pigeons (4 of 4 in Urcuioli, 2011; 5 of 6 in the other two studies) demonstrated reflexivity on AA probe trials when they were trained with AB, BA, and BB identity matching. The same number of Group R pigeons demonstrated reflexivity in Experiment 1 without identity baseline training. Two of four pigeons in Urcuioli (2011) also demonstrated AA generalized identity matching after learning AB, BA, and CC (blue and white hues) identity matching. This still does not explain the two Group C pigeons’ performances, but perhaps the identity relation more easily controls pigeons’ responding even when the reinforcement contingency does not indicate that pigeons should respond on the basis of physical similarity.

It might seem that the performance of all pigeons in Experiment 1 indicates an identity bias. This is just a description of the results and not an explanation for them. In fact, five of six pigeons in Group R that had three tasks including the AC task that provided the elements for class merger demonstrated reflexivity. Only two of four Group C pigeons demonstrated
similar differential responding on reflexivity probe trials. Their responding could be due to random error, but this seems unlikely. If pigeons were to demonstrate a consistent response pattern on probe trials, they should respond at equally high rates to all comparison stimuli on probes—that is responding frequently to triangle and horizontal comparisons regardless of the preceding sample stimulus. This is exactly what pigeons C1 and C4 did when trained with only two tasks. That is, there was a greater frequency of pigeons in Group R demonstrating reflexivity than in the control group (Group C). When C1 and C4 were given the third, AC task, only then did they demonstrate reflexivity. When pigeons C2 and C3 that showed an identity bias received the BC task reversal and the additional AC task, they no longer responded differentially on reflexivity probe trials.

It seems more likely that there is some predisposition for pigeons to preferentially respond to physically identity stimuli even without the reinforcement contingencies. The reinforcement contingencies can enhance or attenuate this predisposition: It was enhanced for the Group R pigeons (Experiment 1), the Group C pigeons that received the AC task (Experiment 3), and the Group O pigeons that received the BC task reversal (Experiment 6). This disposition was attenuated for the Group R and C pigeons that received the BC task reversal (Experiment 2) and the Group O pigeons (Experiment 5). This might also be why fewer Group O (Experiment 5) and Group A pigeons that received the AC task (Experiment 6) showed anti-reflexivity than pigeons
that showed reflexivity. Pigeons are more likely to match physically identical stimuli to one another than physically dissimilar stimuli.

One example of pigeons matching physically identical stimuli to one another without identity or oddity training is from Urcuioli and Swisher (2012b, Experiments 1 & 2). Pigeons were trained on AB hue-form and BA form-hue tasks and tested for AA hue and BB form matching. Four of the seven pigeons responded nondifferentially on these two types of tests, but the other three responded more frequently to the hue and form matching sample-comparison combinations. This effect appears to be transitivity (but not transitivity in the Urcuioli, 2008 sense): Training R → T and T → R should produce R → R transitivity because the red sample and comparison are related to each other via the triangle comparison and sample, respectively. Likewise, the same training (e.g., T → R and R → T matching) can produce T → T transitivity via the common red stimuli across those two baselines, which it did for three of seven pigeons (although see Urcuioli & Swisher, Experiment 3). Pigeons C2 and C3 in Experiment 1 were not demonstrating transitivity, however. They were trained to match T → B and R → T to one another. Because blue and red are different stimuli, they cannot “link” to produce T → T matching. In fact, red is closer to yellow than to blue (e.g., H → Y and R → T matching) which would be more likely to produce H → T oddity (cf. Campos, Urcuioli, & Swisher, 2014; Wright & Cumming, 1971).

Another factor that could result in matching physically identical stimuli to one another is how many “rules” pigeons have to learn in baseline. It should
be easier to acquire relations that require fewer rules rather than more rules. In Zentall, Edwards, Moore, and Hogan (1981), pigeons learned two-alternative oddity and identity tasks by responding away from the matching stimulus on oddity trials and responding to the matching stimulus on identity trials. That is, pigeons responded to whatever was not the red comparison stimulus (e.g., green) on an oddity trial when red was the sample stimulus, and they responded to the red comparison stimulus on an identity trial when red was the sample. On these two different trial types, responding was controlled by the red comparison stimulus—either “reject” red (i.e., respond away from red) or “select” red (i.e., respond to red), respectively. This was apparent when they later substituted different stimuli for the correct comparison stimulus or the incorrect comparison stimulus. Pigeons continued to perform well on oddity trials when the correct comparison stimulus was replaced (e.g., blue for green) and on identity trials when the incorrect comparison stimulus was replaced (e.g., yellow for green). In other words, an identity (matching sample-comparison) relation controlled choices on both the oddity and identity trials.

The pigeons in the present studies had to learn four “rules” for just the reinforced (e.g., “select” or $S^D$) trial types in the two AB and BC tasks (e.g., match $R \rightarrow T$, $G \rightarrow H$, $T \rightarrow B$, and $H \rightarrow Y$) and four “rules” for the nonreinforced (e.g., “reject” or $S^\Delta$) trial types (e.g., do not match $R \rightarrow H$, $G \rightarrow T$, $T \rightarrow Y$, or $H \rightarrow B$). These would not easily translate into a general rule for responding on BB probe trials.
Pigeons can, however, respond to nonmatching relations between stimuli if the reinforcement contingencies yield stimulus classes containing those stimuli. Clearly, few pigeons showed evidence for anti-reflexivity, but the fact that any pigeons showed evidence for anti-reflexivity is an important finding indicating that any inherent identity bias does always not supersede the reinforcement contingencies. The two pigeons in Experiment 5 of the present study that showed anti-reflexivity after training on three arbitrary baseline relations confirm Urcuioli’s (2008) theoretical predictions. The theory does not predict anti-reflexivity after training on only two arbitrary relations, but one control Group A pigeon showed anti-reflexivity. This was not generalized oddity given that he had no history of differential reinforcement of responding to “different” stimuli rather than “same” stimuli (viz., triangle is just as different from red as horizontal lines with reinforced R→T and nonreinforced R→H). Even if this pigeon had ignored ordinal position, there was no clear prediction of how he should respond in testing.

Sweeney and Urcuioli (2010) only had one pigeon demonstrate AA’ “anti-reflexivity” after training AB, BA, and BB’ oddity tasks. Their BB’ oddity task should have made it more likely that pigeons would demonstrate this effect, but with continued testing, two of the pigeons actually matched the physically identical hues to one another on AA probe trials, the opposite of the predicted relation. Similarly, in Urcuioli and Swisher (2012b, Experiment 3) when pigeons were trained with AB hue-form and BA’ form-hue matching (e.g., R→T and T→G matching) and tested for AA’ transitivity (e.g., R→G matching),
three of four pigeons demonstrated AA matching on their second set of tests rather than nonmatching. (They responded nondifferentially on their first set of tests.) None of the pigeons in Experiment 5 of the present study demonstrated reflexivity—they either responded more frequently to the nonmatching BB stimuli than to the matching stimuli or nondifferentially to them.

In addition to demonstrating two new emergent relations predicted by Urcuioli’s (2008) theory (i.e., reflexivity and anti-reflexivity), evidence on probe trials for stimulus class reorganization via a change in the BC baseline task was examined. Campos, Urcuioli, and Swisher (2014) initially provided evidence for stimulus class rearrangement in pigeons. Specifically, pigeons that initially showed BA symmetry after training on AB hue-form, AA, and BB tasks later showed BA anti-symmetry after a change from AA hue identity (or BB form identity) to AA’ hue oddity (or BB’ form oddity) in baseline. When the Group O pigeons from Experiment 5 had their BC (form-hue) baseline relations changed in Experiment 6, they too showed evidence consistent with class reorganization by preferentially responding to the matching form comparison stimulus after the form sample on reflexivity probes.

Pilgrim and Galizio (1996) also reported that apparent class reorganization in some adult humans after baseline reversals. They hypothesized that exposing subjects to fewer training trials with the original baselines prior to the reversal may facilitate class reorganization. The participant with the more typical, extended original baseline training did not show evidence for class reorganization. The Group O pigeons in Experiment 5
generally had *more* experience with their original baselines (e.g., 61-169
sessions) than with their reversed baseline contingencies (e.g., 60-93
sessions) but still showed evidence for class reorganization after a change in
their baseline relations.

It should have been possible to change the stimulus class configuration
for the Group R and C2 and C3 pigeons in Experiment 1 when the BC (form-
hue) baseline relation changed in Experiment 2 as well, but none of the
pigeons responded more frequently to the nonmatching form comparisons than
to the matching form comparison in testing. In fact, four pigeons (viz., R1, R4,
R6, and C2) continued to respond as though their original classes remained
intact with their first set of tests, and two pigeons (e.g., R4 and R5) continued
to demonstrate reflexivity on their second set of tests after the BC task
reversal. The remaining six pigeons responded nondifferentially on the second
set of tests, which suggests that their stimulus classes were no longer [R1, T2,
T1, B2] and [G1, H2, H1, Y2]. Still, this change was not sufficient to produce
evidence for anti-reflexivity on probe trials—i.e., for stimulus class
reorganization of the type [R1, T2, H1, B2] and [G1, H2, T1, Y2].

One difference between the Group R pigeons from Experiment 2 and
the Group O pigeons from Experiment 6 is that the Group O pigeons had more
training sessions with the reversed baselines than the pigeons in Experiment 2
(e.g., 60-93 sessions in Experiment 6 versus 19-72 sessions in Experiment 2
for Group R). Pigeons in Campos, Urcuioli, and Swisher (2014) received 68-
193 sessions on their original AB, AA hue identity, and BB form identity tasks
and 64-246 sessions on their reversed AA’ hue oddity or reversed BB’ form oddity tasks. These pigeons received even more training sessions than the Group O pigeons, and the change in the AA (or BB) task produced evidence for rearranged stimulus classes.

Another, and perhaps more noteworthy, difference is that the Group O pigeons in Experiment 6 were expected to initially show evidence for anti-reflexivity before subsequently showing reflexivity rather than the opposite (i.e., Experiment 2 Group R pigeons). If the reflexivity relation enjoys some advantage over the anti-reflexivity emergent relation beyond that dictated by the reinforcement contingencies, then it is reasonable to expect to see more evidence for reflexivity even after class reorganization than for anti-reflexivity.

Similarly, humans do not always show evidence of stimulus class reorganization on all of their emergent relations tests. Pilgrim and Galizio (1996) note that adults will reverse their responding on symmetry tests with respect to the change in baseline relations but that reflexivity and transitivity test results do not consistently show this same change. Instead, humans continue to respond in accord with their original stimulus classes prior to the baseline reversal. They concluded that the supposedly cohesive properties of an equivalence relation (i.e., reflexivity, symmetry, and transitivity) can become separable, independent relations. The pigeons in the present studies would not be expected to show evidence for any emergent relations other than reflexivity or anti-reflexivity (except for C2 and C3 had they been ignoring ordinal position) due to the fact that they did not receive training with the
necessary baseline relations, but it seems reasonable that pigeons might show the same pattern of results on equivalence tests as humans with more baseline relations and the potential for additional stimulus class members.

At the very least, these results are evidence for as-of-yet unseen emergent reflexivity and anti-reflexivity relations. Pigeons have now demonstrated all of the same emergent relations that humans regularly do without the benefit of language: reflexivity in the present studies, symmetry (e.g., Campos, Urcuioli, & Swisher, 2014; Frank & Wasserman, 2005; Urcuioli, 2008), and transitivity (e.g., Urcuioli & Swisher 2015). Their results also generally conform to the results found with humans when testing for equivalence classes after reversals (e.g., Pilgrim & Galizio, 1996). Even if the equivalence properties do not always hang together after stimulus class formation, there appears to be something common to humans and nonhumans that allows for this basic process of responding to stimuli as though they are interchangeable.
LIST OF REFERENCES


*Journal of the Experimental Analysis of Behavior, 51*, 385-392.


APPENDICES
Appendix A

Table 1

*Successive Matching Contingencies*

<table>
<thead>
<tr>
<th>Group R Experiment 1, Group C Experiment 4, &amp; Group O Experiment 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AB Matching</strong></td>
</tr>
<tr>
<td>R → T - FI 5 s</td>
</tr>
<tr>
<td>R → H - EXT</td>
</tr>
<tr>
<td>G → T - EXT</td>
</tr>
<tr>
<td>G → H - FI 5 s</td>
</tr>
</tbody>
</table>

**Group C Experiment 1**

<table>
<thead>
<tr>
<th><strong>AB Matching</strong></th>
<th><strong>BC Matching</strong></th>
<th><strong>BB Testing</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>R → T - FI 5 s</td>
<td>T → B - FI 5 s</td>
<td>T → T</td>
</tr>
<tr>
<td>R → H - EXT</td>
<td>T → Y - EXT</td>
<td>T → H</td>
</tr>
<tr>
<td>G → T - EXT</td>
<td>H → B - EXT</td>
<td>H → T</td>
</tr>
<tr>
<td>G → H - FI 5 s</td>
<td>H → Y - FI 5 s</td>
<td>H → H</td>
</tr>
</tbody>
</table>

*Note.* The contingencies are shown prior to testing for reflexivity. AB = hue-form, BC = form-hue, AC = symbolic (hue-hue), and BB = form-form. R = red, G = green, T = triangle, H = horizontal, B = blue, Y = yellow, FI = fixed interval schedule, EXT = extinction, ✓ = predicted higher rates of responding on reflexivity probes. The first stimulus (sample) on a trial is shown to the left of the arrows, and the second stimulus (comparison) on a trial is shown to the right of the arrows.
Table 2

**Successive Matching Contingencies**

<table>
<thead>
<tr>
<th>AB Matching</th>
<th>BC Matching</th>
<th>AC Matching</th>
<th>BB Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>R → T - FI 5 s</td>
<td>T → B - EXT</td>
<td>R → B - FI 5 s</td>
<td>T → T</td>
</tr>
<tr>
<td>R → H - EXT</td>
<td>T → Y - FI 5 s</td>
<td>R → Y - EXT</td>
<td>T → H ✓</td>
</tr>
<tr>
<td>G → T - EXT</td>
<td>H → B - FI 5 s</td>
<td>G → B - EXT</td>
<td>H → T ✓</td>
</tr>
<tr>
<td>G → H - FI 5 s</td>
<td>H → Y - EXT</td>
<td>G → Y - FI 5 s</td>
<td>H → H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AB Matching</th>
<th>BC Matching</th>
<th>BB Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>R → T - FI 5 s</td>
<td>T → B - EXT</td>
<td>T → T</td>
</tr>
<tr>
<td>R → H - EXT</td>
<td>T → Y - FI 5 s</td>
<td>T → H</td>
</tr>
<tr>
<td>G → T - EXT</td>
<td>H → B - FI 5 s</td>
<td>H → T</td>
</tr>
<tr>
<td>G → H - FI 5 s</td>
<td>H → Y - EXT</td>
<td>H → H</td>
</tr>
</tbody>
</table>

*Note.* The contingencies are shown prior to testing for anti-reflexivity. The BC matching baselines and the predicted higher rates of responding in testing have changed from those in Table 1.
Table 3

**Overall Predictions**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Group</th>
<th>Predicted</th>
<th>Obtained</th>
<th>Experiment</th>
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</thead>
<tbody>
<tr>
<td>Reflexivity</td>
<td>R</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>5</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Anti-reflexivity</td>
<td>R</td>
<td>6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Symmetry</td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Identity bias</td>
<td>C</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note.* The emergent relations and unpredicted but consistent response patterns on probe trials across all of the experiments are listed. The group indicates for which pigeons the pattern of responding was predicted (or not predicted) and for how many of those pigeons did (obtained) and how many total pigeons were expected (predicted) to demonstrate that relation. The experiment indicates at which point the relation was expected for the different groups of pigeons.
Appendix B

Figure 1. The six gray circles (a) represent the six 2-member stimulus classes that form from the reinforced baseline relations (e.g., R1→T2, T1→T2, and T1→R2) for the pigeons in Urcuioli and Swisher (2012b). Common members across classes that promote class merger are in italics. Ellipses highlight these common stimuli (e.g., T1, T2, H1, and H2) across classes (b). The two 4-member stimulus classes (i.e., [R1, T2, T1, R2] and [G1, H2, H1, G2]) resulting from class merger (c) have dashed arrows indicating the prediction on AA reflexivity probe trials. All other relations were directly trained.
Figure 2. The six gray circles (a) represent the six 2-member stimulus classes that form from the reinforced baseline relations (e.g., R1→T2, T1→B2, and R1→B2) for the Reflexivity group (Group R). Common members across classes that promote class merger are in italics. Ellipses highlight these common stimuli (e.g., R1, B2, G1, and Y2) across classes (b). The two 4-member stimulus classes resulting from class merger (c) have dashed arrows indicating the prediction on BB reflexivity probe. All other relations were directly trained.
Figure 3. The four gray circles represent the four 2-member stimulus classes that form from the reinforced baseline relations (e.g., R1→T2, T1→B2, G1→H2, and H1→Y2 become classes [R1, T2], [T1, B2], [G1, H2] and [H1, Y2]) for the Control group. There are no common members across classes to promote class merger.
Figure 4. Group R acquisition data are shown up to the first two reflexivity test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 5. Group C acquisition data are shown up to the first two test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form) and BC (form-hue) tasks are plotted for each pigeon. Criterion for both tasks was a DR of .80.
Figure 6. Group R reflexivity testing data are shown. The matching and nonmatching trial types and the comparison pecks/s (± 1 SEM) are plotted. The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on AB hue-form matching trials was directly reinforced and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching BB form-form test trials are $T \rightarrow T$ and $H \rightarrow H$ combinations while nonmatching test trials are $T \rightarrow H$ and $H \rightarrow T$ combinations—both nonreinforced.
Figure 7. Group C testing data are shown. The matching and nonmatching trial types and the comparison pecks/s (± 1 SEM) are plotted. The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching (to correspond with Group R) BB form-form test trials are T→T and H→H combinations while nonmatching (to correspond with Group R) BB form-form test trials are T→H and H→T combinations—both nonreinforced.
Figure 8. The six gray circles (a) represent the six 2-member stimulus classes that form from the reinforced baseline relations (e.g., $R1 \rightarrow T2$, $H1 \rightarrow B2$, and $R1 \rightarrow B2$) for Group O. Common members across classes that promote class merger are in italics. Ellipses highlight these common stimuli (e.g., $R1$, $B2$, $G1$, and $Y2$) across classes (b). The two 4-member stimulus classes resulting from class merger (c) have dashed arrows indicating the prediction on $BB'$ anti-reflexivity probe trials. All other relations were directly trained.
Figure 9. Group R acquisition data are shown up to the first two anti-reflexivity test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 10. Group C acquisition data are shown up to the first two reflexivity test sessions after the BC relation reversal (left side for Acquisition 1) and the anti-reflexivity test sessions (right side for Acquisition 2). Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 11. Group R anti-reflexivity testing data are shown (Test 2 and Test 2 continued). For comparison, the reflexivity test data are also shown (Test 1). The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching BB form-form test trials are T→T and H→H combinations while nonmatching BB form-form test trials are T→H and H→T combinations—both nonreinforced.
Figure 12. C2 and C3 test data are shown for the anti-reflexivity probes (BC reversal training—Test 2 and AB, BC, and AC training—Test 3). For comparison, the reflexivity test data are shown (Test 1), prior to which the pigeons received AB and BC training only. The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching (to correspond with Group R) BB form-form test trials are T→T and H→H combinations while nonmatching (to correspond with Group R) BB form-form test trials are T→H and H→T combinations—both nonreinforced.
Figure 13. C2 and C3 symmetry test data are shown. The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BA form-hue test trials. Matching BA form-hue test trials are T→R and H→G combinations while nonmatching BA form-hue test trials are T→G and H→R combinations—both nonreinforced.
Figure 14. C1 and C4 acquisition data are shown up to the first two reflexivity test sessions after adding the AC task. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 15. C1 and C4 test data are shown for the reflexivity probes (AB, BC, and AC training; Test 2). For comparison, the reflexivity test data are also shown (Test 1; AB and BC training only). The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching (to correspond with Group R) BB form-form test trials are T→T and H→H combinations while nonmatching (to correspond with Group R) test trials are T→H and H→T combinations—both nonreinforced.
Figure 16. Group O acquisition data are shown up to the first two anti-reflexivity test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 17. Group A acquisition data are shown up to the first two test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form) and BC (form-hue) tasks are plotted for each pigeon. Criterion for both tasks was a DR of .80.
Figure 18. Group O anti-reflexivity test data are shown. The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching BB form-form test trials are $T \rightarrow T$ and $H \rightarrow H$ combinations while nonmatching test trials are $T \rightarrow H$ and $H \rightarrow T$ combinations—both nonreinforced.
Figure 19. Group A test data are shown. The matching and nonmatching trial types are shown along with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching (to correspond with Group O) BB form-form test trials are T→T and H→H combinations while nonmatching test trials are T→H and H→T combinations—both nonreinforced.
Figure 20. Group O acquisition data are shown up to the first two reflexivity test sessions. Five-block averages are shown along with the attained discrimination. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 21. Group A acquisition data are shown up to the first two anti-reflexivity test sessions. Five-block averages are shown along with the attained discrimination ratio. The AB (hue-form), BC (form-hue), and AC (symbolic) tasks are plotted for each pigeon. Criterion for each task was a DR of .80.
Figure 22. Group O reflexivity test data are shown (Test 2 – Reflexivity) along with the anti-reflexivity test data (Test 1 – Anti-reflexivity). The matching and nonmatching trial types are also shown with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching BB form-form test trials are T→T and H→H combinations while nonmatching test trials are T→H and H→T combinations—both nonreinforced.
Figure 23. Group A anti-reflexivity test data are shown (Test 2 – Anti-reflexivity) along with the anti-reflexivity control test data (Test 1 – Anti-reflexivity Control). The matching and nonmatching trial types are also shown with the comparison pecks/s (± 1 SEM). The baseline data (open circles) are from the AB hue-form baseline trials in test sessions. Responding to the comparison stimuli on the AB hue-form matching trials was directly reinforced, and responding on nonmatching trials was not. The probe data (filled circles) are from the BB form-form test trials. Matching (to correspond with Group O) BB form-form test trials are $T \rightarrow T$ and $H \rightarrow H$ combinations while nonmatching test trials are $T \rightarrow H$ and $H \rightarrow T$ combinations—both nonreinforced.
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B.A. Psychology, Southern Illinois University Carbondale, 2007

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      Thesis Title: Determining the relation between the moments of
      acquisition of baseline conditional discriminations and the
      emergence of equivalence relations

Ph.D. Psychological Sciences, Purdue University, West Lafayette, 2016
      (anticipated)
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Experience:

Graduate Lecturer in Psychology 31400 Introduction to Learning, Summer
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                 and exams, and maintain grade book
Graduate Lecturer in Psychology 38000 Behavior Change Methods, Fall 2015, Spring 2016, Purdue University

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Teaching Assistantship in Psychology 31400 Introduction to Learning, 2010-2016, Purdue University

Job Duties: Maintain grade book, record attendance, guest lecture, and grade quizzes, homework assignments, and exams

Teaching Assistantship in Psychology 20300 Introduction to Research Methods in Psychology, Fall 2014, Purdue University

Job Duties: Maintain grade book, grade exams, and guest lecture

Research Assistantship in Pigeon Laboratory for Peter Urcuioli, 2010-2016 Purdue University

Job Duties: Train and supervise undergraduates who participate in the laboratory for class credit, daily running of birds, program experiments in QuickBasic, data analysis, present articles in laboratory meetings

Experimental Analysis of Human Behavior Laboratory Assistant for Manish Vaidya, 2008-2010, University of North Texas

Job Duties: Recruit and run participants in experiments, design daily sessions for experiments, analyze and present data in laboratory meetings

Operant Laboratory Assistant for Eric Jacobs, 2006-2008, Southern Illinois University Carbondale

Job Duties: Train undergraduate laboratory assistants, oversee and conduct daily operation of laboratory, present articles in laboratory meetings

Neuroscience Laboratory Assistant for Richard Clough, 2006-2007, Southern Illinois University Carbondale

Job Duties: Mount tissue on slides, count GAD, iNOS, GFAP, and other cells, data entry
Professional Affiliations:

Association for Behavior Analysis International, 2006-present
Behavior Analysis Student and Alumni Association, 2008-2010
Mid-American Association for Behavior Analysis, 2006, 2009
Southeastern Association for Behavior Analysis, 2006-2009
Society for the Quantitative Analyses of Behavior, 2006-present
Texas Association for Behavior Analysis, 2008-2009

Research Skills/Interests:

Programming in Visual Basic and QuickBasic, hand shaping marble depositing and lever pressing with rats, hand shaping key pecking with pigeons

Interested in stimulus equivalence in addition to general behavior analysis

Awards and Honors:

Compton Graduate Research Travel Award, 2016, granted by Purdue University. Title of project: Emergent Symmetry and Transitivity in Pigeons

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**Symposia:**


Poster Presentations:


