GENERALIZED IDENTITY MATCHING IN THE PIGEON: ROLE OF EXTENDED OBSERVING- AND CHOICE-RESPONSE REQUIREMENTS

IGUALACIÓN DE IDENTIDAD GENERALIZADA EN LA PALOMA: EL PAPEL DE REQUISITOS EXTENDIDOS DE RESPUESTAS DE OBSERVACIÓN Y DE ELECCIÓN

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Abstract

Four experimentally naïve White Carneau pigeons matched three hues to each other in a variant of an identity matching-to-sample procedure with a fixed-ratio 20 on samples and a response-initiated fixed-interval 8 s on comparisons. The extent to which the pigeons were matching on the basis of identity was assessed by presenting, in extinction, test trials comprising novel stimuli serving as the sample and comparison stimuli. When the test trials were comprised only of novel stimuli, three out of the four pigeons demonstrated substantially above-chance levels of accuracy. These data suggest that the extended observing- and choice-response requirements facilitate the development of generalized identity matching performance.

Keywords: generalized identity matching, observing response requirement, choice response requirement, matching to sample, key peck, pigeons

Resumen

Cuatro palomas White Carneau experimentalmente ingenuas igualaron tres tonalidades de color a sí mismas en una variante de un procedimiento de igualación a la muestra por identidad con un programa de razón fija 20 en los estímulos muestra y un intervalo fijo 8 s iniciado por la respuesta en los estímulos de comparación. La medida en la que las palomas igualaron con base en la identidad fue evaluada presentando en extinción ensayos de prueba que consistían en estímulos novedosos que funcionaron como los estímulos de muestra y comparación. Cuando los ensayos de prueba consistieron sólo en estímulos novedosos, tres de las cuatro palomas mostraron niveles de precisión sustancialmente arriba del azar. Estos datos sugieren que los requisitos extendidos de respuesta de observación —y elección— facilitan el desarrollo del desempeño de igualación de identidad generalizada.

Palabras clave: igualación de identidad generalizada, requerimiento de respuesta de observación, requerimiento de respuesta de elección, igualación a la muestra, picoteo a la tecla, palomas

In a typical identity matching-to-sample (MTS) procedure[1] (e.g., Cumming & Berryman, 1965), a trial begins with the presentation of a sample stimulus. A response to the sample stimulus, called an observing response, produces two or more comparison stimuli. A response to the comparison stimulus that is physically identical to the sample stimulus is reinforced, whereas a response to the other comparison stimuli is extinguished. Once the subjects learn to respond accurately, they are tested with novel stimuli. Generalized identity matching is said to be demonstrated if they respond accurately on the novel-stimuli test trials (Dube, McIlvane, & Green, 1992).

Some nonhuman species, such as chimpanzees (e.g., Oden, Thompson, & Premack, 1988), capuchin monkeys (e.g., Barros, Galvao, & McIlvane, 2002), and sea lions (e.g., Kastak & Schusterman, 1994), learn generalized identity matching. The literature with pigeons is a bit more complicated. When the number of trials required to learn a new MTS task served as the dependent measure, some convincing evidence was obtained in the form of faster acquisition across successive sets (e.g., Zentall, Edwards, Moore, & Hogan, 1981).When accuracy on the test trials with novel stimuli served as the dependent measure, however, most results are negative (e.g., Cumming & Ber-

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[1] The term *matching* and *matching-to-sample* can refer to both procedure and performance (Mackay & Sidman, 1984). When the term is used to describe the procedure in this article, the word *procedure* will always follow the term (e.g., identity matching-to-sample procedure). When the term is used to describe the performance, on the other hand, the term will be used by itself (e.g., generalized identity matching).

ryman, 1961; Katz, Bodily, & Wright, 2008) or equivocal (e.g., Colombo, Cottle, & Frost, 2003; Sacks, Kamil, & Mack, 1972). Colombo et al., for example, found that accuracy on the test trials was above chance levels when a fixed-ratio (FR) 20 observing-response requirement was implemented. The results are difficult to interpret, however, because correct responses on the test trials were reinforced, and the accuracy steadily improved as a function of test sessions (see also Sacks et al., 1972, for similar results with the same limitation).

There are a few notable investigations that used accuracy on test trials as a dependent measure but provided more convincing evidence of pigeons learning generalized identity matching. In Wright, Cook, Rivera, Sands, and Delius's (1988) experiment, one group of pigeons was trained with two stimuli that were presented repeatedly in daily sessions. The other group was trained with 152 stimuli in a *trial-unique* procedure in which daily sessions comprised only one presentation of each of the stimuli. In tests with novel stimuli, the group trained with a large number of exemplars performed with considerably higher accuracy. These results were successfully replicated by Bodily, Katz, and Wright's (2008), in which the number of training stimuli was systematically manipulated and the accuracy on test trials improved as a function of the number of training stimuli.

Wright (1997) compared the effects of extended observing-response requirements on generalized identity matching. Four groups of pigeons (Groups 0, 1, 10, and 20) learned three conditional relations. For Group 0, the sample and comparison stimuli appeared simultaneously. For Groups 1, 10, and 20, the observing-response requirement was FR 1, 10 and 20, respectively. The likelihood of accurate responses on test trials with novel stimuli increased as a function of the number of observing responses required. When this experiment was replicated with the vertical display of the stimuli on a response panel, as opposed to the horizontal display of the stimuli on the floor as in Wright, however, Katz et al. (2008) found that the extended observing-response requirement did not produce generalized identity matching.

Taken together, the literature on generalized identity matching in pigeons shows that there are three experiments (Bodily et al., 2008; Wright, 1997; Wright et al., 1988) that unambiguously demonstrate that pigeons can learn generalized identity matching. Given these successes, the question of whether pigeons can learn generalized identity matching has been answered in the affirmative. It is not entirely clear, however, what variables are responsible for the successful demonstrations. Wright et al. (1988) and Bodily et al. (2008) documented generalized identity matching with a large number of stimuli, but Wright (1997) reported equally good results after training with only three stimuli. In addition, Wright emphasized the role of extended observing-response requirements, but Wright et al., who had programmed fixed interval (FI) 2-s observing response requirements, did not. Also, all of the three experiments used

innovative but unconventional procedures during training and testing, including: the use of color cartoons as stimuli presented on a touchscreen monitor, horizontal display of the stimuli (cf. Bodily et al., 2008, where a vertical display was employed), 8- or 10-s presentation of the correct comparison stimulus following a correct choice while the subject consumed the grain, and the use of a trial-unique testing procedure whereby each of the novel stimuli was presented only once. These features make it hard to unequivocally point to the mechanisms responsible for the highly accurate performance. A better understanding of such mechanisms might result from systematically replicating the critical procedural features in these investigations under relatively conventional circumstances.

The purpose of the current experiment was to examine whether extended observing- and choice-response requirements could produce key-color generalized identity matching in pigeons. In a conventionally configured operant chamber, pigeons were trained on three-hue conditional discrimination task, which was followed by transfer tests with novel stimuli. In an effort to equate the current procedure with that in Wright (1997) and Katz et al. (2008), an FR 20 observing-response requirement was implemented. In addition, a response-initiated FI 8-s schedule (Shull, 1970) was implemented on the correct comparison stimulus to better approximate the time Wright's pigeons spent in the presence of the correct comparison stimulus. It is important to note that all three experiments that demonstrated pigeons' learning generalized identity matching unambiguously (Bodily et al., 2008; Wright, 1997; Wright et al., 1988) employed a procedure in which a correct comparison stimulus remained for 8 or 10 s after a correct comparison choice was made, whereas Katz et al., who failed to replicate Wright (1997), did not employ such a procedure. It also is important to note that, unlike the previous experiments using an extended observing response requirement in a conventional operant chamber (Colombo et al., 2003; Sacks et al., 1972), no differential reinforcement was provided on test trials with novel stimuli. By precisely articulating the behavioral mechanisms involved in successful demonstrations of generalized identity matching in pigeons (or avian) and comparing the mechanisms across a variety of species including humans, we could deepen our knowledge on how humans and nonhuman animals learn this abstract concept that is essential for various higher cognitive abilities.

Method

Subjects

Four experimentally naive White Carneau pigeons served as subjects. The pigeons were housed individually in stainless steel cages in a temperature controlled colony room with a 12-h lights-on lights-off cycle with grit and water continuously available.

Each pigeon was maintained at 75 or 80% of its free-feeding body weight throughout the experiment via post-session feedings when necessary. Experimental sessions were conducted six days per week as long as the subjects' weights were within ± 15 grams of their established running weight.

Apparatus

Sessions were conducted in a sound-attenuating operant-conditioning chamber with the front panels constructed of stainless steel and the walls constructed of plywood with the outside walls covered with acoustic tiles. The experimental space measured 31 cm high, 51 cm wide, and 34 cm deep. General illumination was provided by a 28-V houselight located in the horizontal center and 2 cm below the ceiling. Three translucent response keys on the front panel were 2.5 cm in diameter, 6.5 cm apart center to center, and aligned horizontally in a row 8 cm from the ceiling. The response keys could be illuminated with a variety of hues and geometric forms by projectors (ENV-130M; MED Associates, St. Albans, VT) mounted behind the keys. Access to mixed grain was provided by raising a food hopper for brief periods. A small light provided diffuse illumination in the magazine when the hopper was operated. A fan located on top of the chamber provided ventilation and white noise. The experimental contingencies were controlled by MED-PC software (Version 4) on an IBM-compatible computer located on a table near the chamber.

Procedure

Preliminary training. All pigeons initially were trained to peck the keys illuminated with a white light by the differential reinforcement of successive approximations. Next, they were trained to peck the center key and then an illuminated side key. A trial began with the illumination of the center key. A single peck on the center key turned off the center key and illuminated one side key with the same hue as the one presented on the center key. The other side key remained dark. A single peck on the illuminated side key turned off all lights in the chamber and raised the hopper for 3 s. This was followed by a 15-s intertrial interval during which all lights in the chamber were turned off.

Pigeons then were trained to peck the center key 20 times (FR20) and the illuminated side key on which a response-initiated FI 8-s schedule was operative. As the first step, the FR requirement on the center key was increased from 1 to 20 over several sessions. Once the pigeons were reliably pecking at the sample stimulus 20 times, the response-initiated FI 8-s schedule was implemented on the side key. In this procedure, a single peck on an illuminated side key turned off the center key light and

initiated a timer. The first peck on the illuminated side key after 8 s had elapsed was reinforced. A peck on any dark key or a peck on the center key after the side key was illuminated had no programmed consequences. Three hues—red, green, and white—were presented quasirandomly, with the restrictions that each hue was presented equally often and the same hue was presented on no more than two consecutive trials. For the duration of the experiment, the number of trials was 36 across all pigeons, and the reinforcement duration was 2, 3, 5, and 3 s for Pigeons 1050, 1064, 1079, and 1457, respectively. This training continued until pigeons' latencies to start pecking the sample stimulus and the time needed to complete the FR requirement on the sample were stable, as judged by visual inspection.

Baseline training. Each pigeon was exposed to a simultaneous identity matching-to-sample procedure with an FR 20 observing-response requirement on the sample stimuli and a response-initiated FI 8-s requirement on the matching comparison stimuli. The procedure was identical to the preceding training conditions except that both side keys were illuminated following completion of the response requirement on the center key: one with a hue identical to the one illuminated on the center key and the other with one of the two nonmatching hues. A single peck on the side key with the matching stimulus turned off the sample stimulus and the nonmatching comparison stimulus and initiated the FI 8-s timer. A single peck on the nonmatching side key turned off all lights in the chamber. No correction procedure was used throughout the experiment.

The three *problems*—matching white, green, and red hues in a simultaneous conditional discrimination procedure—result in 12 individual configurations when the presentation of the matching hue is counterbalanced with respect to location and the accompanying nonmatching hue. The daily sessions of 36 trials consisted of three presentations of a randomized block of these 12 configurations.

After a minimum of 40 sessions and 90% or higher accuracy was observed for five consecutive sessions, the probability of reinforcement was reduced to .5. This was arranged to prepare the pigeons for the subsequent test trials on which correct responses were not reinforced. The training with .5 probability of reinforcement continued for a minimum of 10 sessions and until 90% or higher accuracy was maintained for five consecutive sessions.

Generalized identity matching test. Pigeons were exposed to two broad types of tests—ones in which novel stimuli (yellow or blue) were presented against already trained hues (red, green, and white) or ones in which they were presented against each other (yellow and blue). A test with yellow (hereafter yellow test) was conducted first, which was followed by a test with blue (blue test) and then a test with both yellow and blue (yellow-blue test). Each test was composed of four test sessions. At least five consecutive sessions in which 90% or higher accuracy was maintained

were interspersed between the three tests and between the first two and last two sessions of each test. A test session consisted of 12 test trials quasi-randomly intermixed with 24 training trials with all training configurations. The procedure was identical to that in the preceding baseline training except that, because no reinforcement was available in the 12 test trials, the probability of reinforcement on the 24 training trials was increased to .75 to equate the overall probability of reinforcement between the test and the training conditions. In the yellow or the blue test, each novel stimulus served as the sample and the matching comparison stimuli in half of the test trials (hereafter S+ trials), whereas in the other half of the test trials, each novel stimulus served as the nonmatching comparison stimulus (hereafter S- trials). A training stimulus served as the nonmatching comparison stimulus on the S+ trials (e.g., yellow, yellow, and red lights on the left, center, and right keys, respectively), whereas each training stimulus served as the sample and matching comparison stimuli on the S- trials (e.g., red, red, and yellow lights). The hue and location of the stimuli were counterbalanced. In the yellow-blue test, which was not originally planned but was conducted given the results of the yellow and the blue tests, test trials were composed of only yellow and blue as novel stimuli and no training stimulus was presented on the test trials. When yellow served as the sample and matching comparison stimuli, for example, blue served as the nonmatching comparison stimulus (e.g., yellow, yellow, and blue lights).

Results

All four pigeons acquired the conditional discriminations with the training stimuli with 90% or higher accuracy. The mean accuracy for the last five sessions of the terminal training condition was 94.4%, 96.7%, 96.1%, and 96.1% for Pigeons 1050, 1064, 1079, and 1457, respectively.

Figure 1 shows the overall accuracy (four test sessions combined) on trials with one or two novel stimuli as the sample and correct comparison stimuli during the yellow, blue, and yellow-blue tests. In the yellow and the blue tests, only for one pigeon (1457), the accuracy was substantially above chance levels ($p = .003$ for the yellow test and $p = .032$ for the blue test, binomial test, the alpha level = .05). In the yellow-blue test, on the other hand, for three out of the four pigeons, the accuracy was substantially above chance levels ($p = .015$ for 1050, $p = .003$ for 1079, and $p = .001$ for 1457, binomial test).

Figure 2 shows accuracy on all three types of trials (S+, S-, and training trials) in each of the four test sessions, individually. For the yellow and the blue tests, the accuracy on the S+ trials steadily deteriorated across test sessions, whereas the accuracy on the S- trials improved (except for Pigeon 1064's blue test and Pigeon 1457's

yellow and blue tests). For the yellow-blue test, on the other hand, no systematic pattern was observed on trials with novel stimuli. For two pigeons, accuracy improved across sessions, and for the other two pigeons, the accuracy remained relatively stable. Finally, the accuracy on trials with the training stimuli remained high across test sessions.
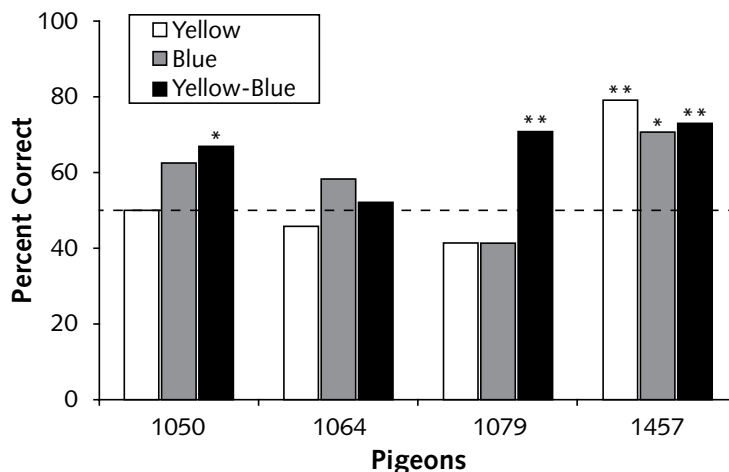

Figure 1. The overall accuracy on the test trials for four test sessions combined together during the yellow (white bars), blue (gray bars), and yellow-blue (black bars) tests. The dashed horizontal line represents chance levels of accuracy. * $p < .05$. ** $p < .01$.

Figure 3 shows accuracy on both S+ and S- trials as a function of trial types in the yellow and the blue tests (e.g., "Y & W" refers to a trial type in which yellow and white served as the sample and nonmatching comparison stimuli, respectively). For each pair of bars, the left bar shows accuracy from the first two test sessions and the right bar from the last two. This analysis is designed to show the extent to which the subjects discriminated between the novel and training stimuli. For example, chance levels of accuracy on both S+ and S- trials throughout the test sessions may indicate stimulus generalization between the novel and training stimuli, whereas high accuracy on one trial type but low accuracy on the other trial type, even during the half of the test sessions, would rule out generalization and suggest subjects discriminated between the novel and training stimuli.

For example, Pigeon 1079's accuracy on trials involving yellow and white stimuli in the yellow test (Y & W trial types) was at chance for both S+ and S- trials during the first two test sessions but highly differentiated during the last two test sessions
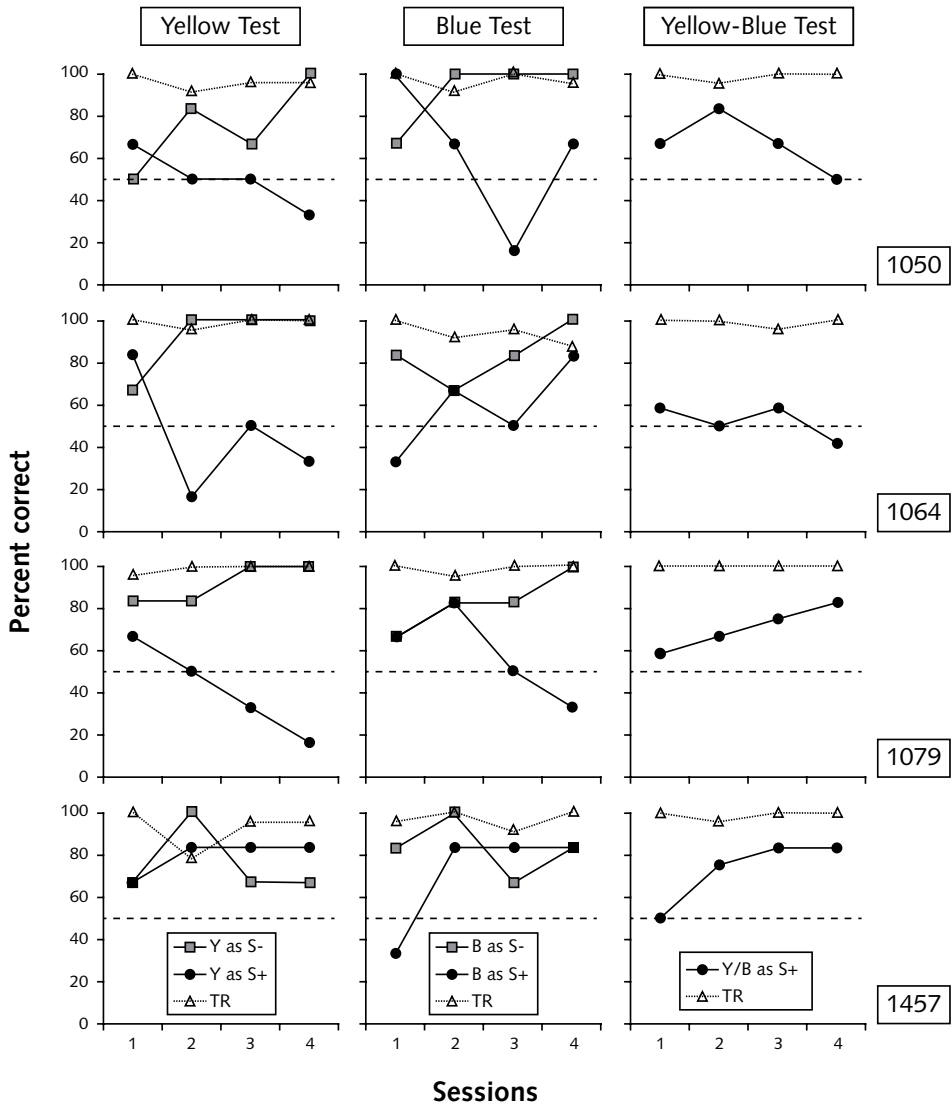
Figure 2. Accuracy on the S- (square), S+ (circle), and training (triangle) trials for individual test sessions during the yellow (left column), blue (center column), and yellow-blue (right column) tests. The dashed horizontal line represents chance levels of accuracy.
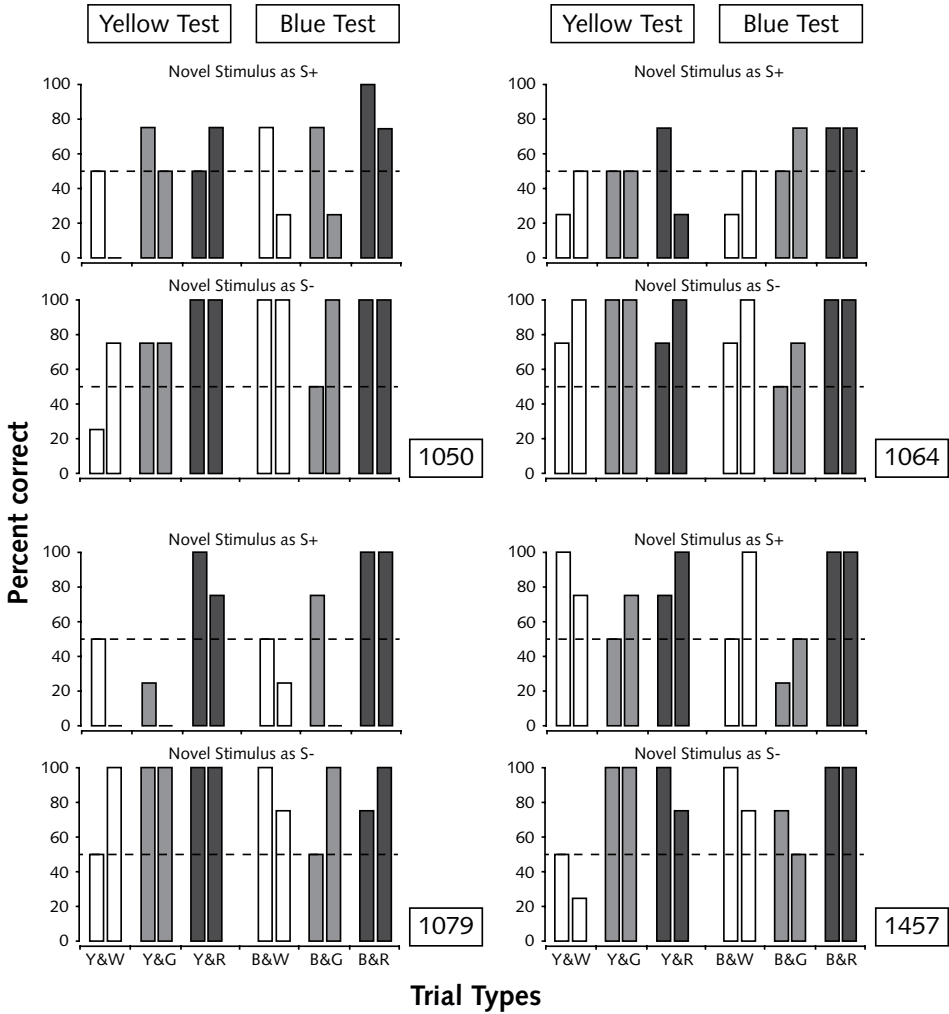
Figure 3. Accuracy on the S+ and S- trials as a function of trial types during the yellow and the blue tests. Trial type "Y & W," for example, refers to trials in which the yellow and white stimuli were presented. For each pair of bars, the left bar represents accuracy from the first two test sessions and the right bar from the last two. The dashed horizontal line represents chance levels of accuracy.

(i.e., 0% on S+ trials and 100% on S- trials). This pattern of choices shows that yellow and white were perfectly discriminated during the last two test sessions—Pigeon 1079 avoided yellow on all trials involving yellow and white. This pigeon also avoided blue on all trials involving blue and green during the last two test sessions. Similarly, Pigeon 1050 avoided yellow and blue during the second half of the yellow and the blue tests, respectively, suggesting that this pigeon discriminated between the novel stimuli and the stimuli used during training. Pigeon 1064, which did not show high accuracy on the yellow-blue test, avoided yellow when presented against white, but there was no clear evidence that this pigeon discriminated between blue and green. Finally, during the yellow test, Pigeon 1457 preferred yellow when presented against white, another pattern indicating discrimination between yellow and white. During the first half of the blue test, this pigeon avoided blue when presented against green. Taken together, this analysis indicates that the pigeons discriminated between the novel stimuli and stimuli used during training stimuli. The only exception was Pigeon 1064's discrimination between blue and green.

Discussion

Four experimentally naïve pigeons learned three conditional discriminations under an FR 20 observing-response requirement and a response-initiated FI 8 s for correct comparison choices. On the one hand, when one test stimulus was presented during the yellow and the blue tests, only one pigeon showed substantially above-chance levels of accuracy. When both test stimuli were presented on the test trials, on the other hand, three out of the four pigeons showed substantially above-chance levels of accuracy. Detailed analyses of the test performance show that the pigeons avoided the novel stimulus when paired with the training stimuli. This indicates that the pigeons discriminated between the test and training stimuli, thus ruling out the possibility that the accurate performance resulted from pigeons' failure to discriminate between the test and training stimuli.

The present experiment makes some important contributions to the understanding of generalized identity matching in pigeons. First, because an extended observing-response requirement is known to facilitate the acquisition of conditional discriminations (Sacks et al., 1972), the possibility of rapid learning was an issue in the previous experiments in which correct responses on the test trials with novel stimuli were reinforced (e.g., Colombo et al., 2003). In the present experiment, correct responses on the test trials were not reinforced, which rules out the possibility that pigeons simply learned the MTS task rapidly. Second, unlike the previous experiments by Wright and his colleagues (e.g., Bodily et al., 2008; Wright, 1997; Wright et al., 1988), in which

unconventional procedures (e.g., color cartoons on the touchscreen and use of the trial-unique testing procedure) were employed, the present experiment was conducted under conventional circumstances (e.g., hues presented on response keys and repeated exposures to test stimuli). The present results suggest that the color cartoons and the trial-unique testing procedure used by Wright and his colleagues were not essential for their successful demonstrations (but see a discussion on a potential role of the horizontal stimulus display below).

Finally, the present results demonstrate that both extended observing- and choice-response requirements may play a critical role in producing generalized identity matching in pigeons. This conclusion is supported by several previous experiments. Katz et al. (2008) demonstrated the extended observing-response requirement alone did not produce generalized identity matching, suggesting the importance of the choice-response requirement. Unpublished data collected by the second author further suggest insufficiency of an observing-response requirement. Vaidya, Willhem, and Branch (1999) first tested pigeons' generalized identity matching with an FR 20 observing-response requirement in a conventional operant chamber and found that accuracy on test trials with two novel hues was at or around chance. They then added a response-initiated FI 8-s schedule on the correct comparison stimulus in a similar manner as in the present experiment and found that for four out of the five pigeons, accuracy on test trials improved to 70%—a substantial improvement relative to the first test. The fact that the test stimuli were not completely novel (e.g., there exists the possibility of stimulus generalization), however, raises some doubts about the strength with which such a claim could be defended. With respect to sufficiency of an extended choice-response requirement, Wilkie and Spetch (1978) found that an extended choice-response alone did not improve (indeed decreased) accuracy in a delayed MTS procedure in pigeons. Although effects of an extended choice-response requirement on generalized identity matching should be explicitly tested, the finding would suggest that an extended choice response alone may not be sufficient for generalized identity matching. Taken together with these previous experiments, the present results suggest that both extended observing- and choice-response requirements play an important role in generalized identity matching in pigeons, although further research is invited to replicate and confirm the finding.

Despite the fact that accuracy on test trials was above chance levels, the robustness of the finding was at best modest in that the accuracy was not as high as that on trials with training stimuli. This is in contrast to experiments by Wright and his colleagues who observed the accuracy on the test trials was as high as that on the trials with the training stimuli (e.g., Wright, 1997). This difference may be accounted for at least in part by the unconventional procedures employed in experiments by Wright and his colleagues. Katz et al. (2008) employed color cartoons as stimuli and a tri-

al-unique testing procedure, but the accuracy on test trials was around chance levels. By exclusion, this highlights the potential importance of a vertical stimulus display (cf. that Wright and his colleagues employed a horizontal stimulus display). The way that pigeons view stimuli differ between vertical and horizontal stimulus displays. Katz et al. suggested that a horizontal display would favor the development of generalized identity matching because pigeons typically view stimuli from an upright position first and then bend down to peck them, which allows them to view the sample and comparison stimuli simultaneously and thus facilitates their learning to respond to the relations between stimuli. Perhaps, the vertical stimulus display in the present experiment interfered with the pigeons' learning to respond on the basis of the identity of the stimuli in some ways, although such deleterious effects were overcome by the use of extended observing- and choice-response requirements, which resulted in the modest magnitude of generalized identity matching observed.

Another possible reason for the modest test performance was the use of extinction during the test trials. In the test sessions, pecking the matching comparison on the training trials was reinforced 75% of the time, whereas pecking the novel matching comparison on the test trials was never reinforced. Three of the four pigeons (1050, 1064 and 1079) in the yellow test and two pigeons (1050 and 1079) in the blue test showed above-chance levels of accuracy on the S+ test trials during the first test session. These pigeons' accuracy, however, deteriorated across subsequent test sessions even as performance on the S- trials steadily became more accurate. These outcomes suggest that the pigeons avoided the novel stimulus on both types of tests trials. Note that the above-chance levels of accuracy on the S+ test trials during the first test session suggests that the later tendency to avoid the novel stimulus was not due to novelty per se but rather due to local extinction of novel stimulus choices (see Wright et al., 1988, for a related discussion). When the pigeons were forced to peck the novel stimuli during the yellow-blue test, which was the very reason that this test was designed given the results of the yellow and the blue tests, the accuracy on the test trials improved. Despite this improvement, it is unknown how the previous history of local extinction affected the pigeons' performance during the yellow-blue test. It is at least possible, therefore, that the modest test performance was in part due to the local extinction.

The present experiment represents an early step in a shift in the research strategy from attempts to demonstrate generalized identity matching with pigeons to (now) attempting to understand the mechanisms underlying generalized identity matching. Future directions in this line of research could attempt to isolate other features of the successful demonstrations to determine the relative importance of each variable in the production of generalized identity matching. If we could understand how to produce the performance on demand, we can fruitfully use these complex performances

as baselines for all manner of interesting questions about the nature of abstract concept learning in nonhuman animals. Finally, the ability to produce generalized identity matching without verbal instructions could inform the development of technologies for use with young children or individuals with intellectual and developmental disabilities.

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