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Learning Strategies in Matching to Sample: If-then and Configural Learning by Pigeons

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Abstract

Pigeons learned a matching-to-sample task with a split training-set design in which half of the stimulus displays were untrained and tested following acquisition. Transfer to the untrained displays along with no novel-stimulus transfer indicated that these pigeons learned the task (partially) via if-then rules. Comparisons to other performance measures indicated that they also partially learned the task via configural learning (learning the gestalt of the whole stimulus display). Differences in the FR-sample requirement (1 vs. 20) had no systematic effect on the type of learning or level of learning obtained. Differences from a previous study (Wright, 1997) are discussed, including the effect of displaying the stimuli vertically (traditional display orientation) or horizontally from the floor.

Tasks that can be learned by using different strategies have been a focus for psychology. Developing procedures to assess which strategies are learned has challenged the ingenuity of psychology researchers. One might even suggest that the success of comparative cognition depends on such developments to assess our models and theories (Roitblat & Weisman, 1986). The matching-to-sample (MTS) task is a procedure that can be solved by different strategies, either relational or item-specific strategies (e.g., Carter & Warner, 1978; Cumming & Berryman, 1965; Katz, Wright, & Bodily, 2007; Mackintosh, 2000; Roberts, 1998, p92; Urcuioli & Nevin, 1975; Wright, 1997; Zentall, Edwards, Moore, & Hogan, 1981).

In typical MTS tasks, the subject is first presented with a sample item (e.g., red). After an observing response to the sample, two comparison stimuli (e.g., red and blue) are typically presented. The correct response is to select the comparison stimulus (red) that matches the sample. If the subject learns the MTS task relationally (i.e., relating each comparison stimulus to the sample stimulus), then this relational learning can provide the basis for abstract-concept learning. To test for abstract-concept learning (and relational learning) the subject is tested with novel stimuli. If the subject has learned the abstract concept, it should match novel stimuli as accurately as training stimuli. If, on the other hand, the subject learned the MTS task item-specifically, then the subject could have learned the configural pattern of the stimulus displays or the if-then rule for each of the stimulus combinations. Configural learning refers to learning the whole gestalt of each display and learning which comparison choice to make based on this

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global pattern. If-then rule learning refers to learning specific stimulus-response chains to the sample and correct comparison stimuli (e.g., if red sample then select red comparison stimulus).

The MTS task can be learned by many species including capuchin monkeys (*Cebus apella* and *Cebus apella apella*), chimpanzees (*Pan troglodytes*), dolphins (*Tursiops truncatus*), humans (*Homo sapiens*), orangutans (*Pongo pygmaeus*), pigeons (*Columba livia*), rats (*Rattus norvegicus*), rhesus monkeys (*Macaca mulatta*), and sea lions (*Zalophus californians*) (e.g., Herman, Hovancik, Gory, & Bradshaw, 1989; Kastak & Schusterman, 1994; Oden, Thompson, & Premack, 1988; Pena, Pitts, Galizio, 2006; Robinson, 1955; Weinstein, 1941; Wright, 1997). Discovering which of these modes of learning (i.e., strategies) and what factors influence which strategy will control performance in monkeys and pigeons is an objective of our research. The experiment reported here focuses on what pigeons learn in MTS tasks in traditional (i.e., vertical display orientation) operant chambers.

The literature is replete with failures of pigeons to show abstract-concept learning through transfer to novel stimuli in the MTS task. Therefore, it was thought at one time that pigeons were not capable of learning abstract concepts (e.g., Premack, 1978, 1983). However, if pigeons are trained with a large number of items (i.e., 152), they then fully learn the abstract concept (Wright, Cook, Rivera, Sands, & Delius, 1988). By full abstract-concept learning we mean that performance on transfer trials is statistically equivalent to performance on baseline trials. Even when pigeons are trained initially with a small number of items (i.e., 3) and do not learn the abstract concept, they do learn the abstract concept when the training set is progressively increased (Bodily, Katz, & Wright, in press).

An issue that has puzzled investigators for some time is when subjects do not learn the abstract concept, what do they learn? Common wisdom has been that when they do not learn the abstract concept, they learn if-then rules (Carter & Eckerman, 1975; Carter & Werner, 1978; Skinner, 1950). But if-then rule learning had remained an untested hypothesis for 20 or more years. Wright (1997) developed a definitive test of if-then rule learning when he divided the 12 possible displays constructed from three items (apple, duck, grapes) into two separate sets of six displays (see Figure 1). In this split-set design, only one set of six displays was used (trained) to train the MTS discrimination and the other set (untrained) was saved to test for if-then rule learning. Note that each item was presented an equal number of times as the sample, and as the correct and incorrect comparison stimulus. If subjects learned if-then rules, then they should have transferred to the untrained set because the same if-then rules can be applied (i.e., if apple then select apple comparison). If subjects learned configural rules, then they should not have transferred to the untrained set *and* to novel stimuli, but should still have learned the task.

Another factor in Wright (1997) was observing response. Pigeons were trained with either a FR 0, 1, 10, or 20 to the sample. Pigeons in the FR0 and FR1 groups did not learn the abstract concept, but learned the MTS task by configural rules. When pigeons (FR20 group) did learn the abstract concept fully they transferred to the untrained set at the same level as novel transfer, as they were applying the abstract concept. When pigeons (FR10 group) learn the abstract concept partially (between baseline and chance) they transferred to the untrained set at the same level as novel transfer, as they were applying the abstract concept at the same partial rate to these untrained stimulus displays. In any case, none of the groups in the Wright (1997) study showed any evidence of if-then rule learning.

Wright (1997) suggested that a critical factor in getting pigeons to fully learn the abstract concept was the number of observing responses required to the sample. Another factor, untested in Wright (1997), was the role of presenting the stimuli from the chamber floor. In the Wright study, the computer monitor pointed up from the floor and correct responses were rewarded with seeds placed directly on top of the matching comparison stimuli. By contrast, most other

MTS experiments with pigeons have presented stimuli from a traditional vertically orientated stimulus panel where the pigeon stands upright and pecks straight ahead at stimuli presented from the front wall (but see Wright et al., 1988; Wright & Delius, 1994; Lombardi, 2007). It has been suggested that the increased ecological validity of a horizontal orientation may lead to optimal learning (Delius, 1992). The increased FR may be particular to the situation of projecting stimuli from the chamber floor. Related, pigeons trained in MTS on three images in a traditional operant chamber (i.e., with a vertical stimulus panel) and a FR10 sample response requirement did not demonstrate any abstract-concept learning (Bodily et al., in press). There was not even the partial concept learning by pigeons trained with an FR10 found by Wright (1997). These findings led us to ask what the pigeons from Bodily et al. learned when they failed novel-stimulus transfer. In the present study, we employed the split-set design (Wright, 1997) in a traditional operant chamber to investigate what pigeons trained similarly to those in the Bodily et al. study were learning when they did not learn the abstract concept.

Method

Subjects

The subjects were eight naïve White Carneaux pigeons (*Columba livia*). Testing was conducted 5–7 days a week. The pigeons were maintained at approximately 80–85% of their free-feeding weights. Free access to grit and water was provided in the pigeons' individual home cages. A 12-hr light-dark cycle was maintained in the colony room.

Apparatus

Chamber—The chamber was a wooden box (38-cm wide × 36.5-cm deep × 39.5-cm high). In the back panel, an axial fan, Dayton Electric (Model 4WT40), provided both ventilation and noise. A houselight (lamp #1829) centered in the ceiling provided internal lighting during intertrial intervals (ITI). The food hopper (custom design), operated by a computer-controlled relay interface (Keithley, ERA-01), was centered below the monitor (Eizo Flexscan T566; 17-inch flat screen CRT; 800 × 600 pixel resolution). A thin piece of glass mounted in a 25 × 17.5-cm viewing window separated and protected the monitor from the pigeon's pecks. An infrared touchscreen (Carroll Touch, UniTouch 17"), framed the viewing window and detected pecks at the monitor.

Stimuli—Stimuli were color, computer-drawn, cartoon images (2.5-cm high × 3-cm wide at 28 pixels/cm). The stimuli were nearly identical to those used in the Wright (1997) study, except for their adaptation to the more modern, higher resolution monitor. Stimuli were arranged in the display such that the sample and comparisons formed a triangle (19.05 × 7.78 cm). The sample stimulus appeared centered horizontally at approximately 8 cm above the bottom of the monitor. Comparison stimuli appeared centered at 4 cm above the bottom with the left and right comparisons appearing 9 cm and 25 cm from the left side of the monitor, respectively. Examples of the training items (apple, duck, grape) are seen in display from in Figure 1. Examples of testing items are seen in Figure 2 and can also be seen online in Wright, 2001.

Experimental control—Experimental events were controlled and recorded using custom software written in Visual Basic 6.0 on a microcomputer (Dell Dimensions 2100). A video card (ATI Xpert 98) controlled the monitor on which stimuli were presented. A PCI card (Keithley KPCI-PI0, Cleveland, OH) controlled the relay interface that operated the hopper, hopper-light, and house-light.

Procedure

Pretraining—Naïve pigeons were trained by hand to eat from the food hopper. Responding was then autoshaped to the three training items (apple, duck, and grapes). Location (left or right comparison) and stimulus presentation were counterbalanced within a session. Stimuli appeared on separate trials and randomly occurred 24 times in an 84-trial session. A stimulus was presented for 10 s, following which the food hopper was raised for 5-s. Pecking the stimulus extinguished it and immediately raised the food-hopper. A 50-s ITI separated trials. Once pigeons began consistently pecking the stimuli, a response dependent (FR1) procedure was implemented. This procedure was identical to the autoshaping procedure with the exception of response dependent food access (stimuli were presented until pecked) and a 15-s ITI. The response dependent procedure was used until rapid and consistent responding was maintained throughout a session.

Training—The training (and testing) procedure was similar to that used by Wright (1997). There were two groups of pigeons with different observing-response requirements, FR1 ($n = 2$) and FR20 ($n = 6$), otherwise the procedures were the same. For the FR20 group, the response requirement to the sample (FR) was systematically increased over several sessions. Upon completion of the FR, two comparison stimuli were simultaneously presented. The sample and two comparison stimuli remained in view until a choice occurred. A peck to the matching comparison stimulus was followed by 3-s access to mixed grain. A peck to the incorrect comparison stimulus was followed by an 8-s timeout. Both outcomes were followed by a 15-s ITI. Starting on the second training session, incorrect choices were followed by a repeat of the incorrect trial (correction procedure). The training set consisted of the three colored cartoon items: an apple, a duck, and grapes. With three training stimuli there are 12 different display configurations. Only six of these displays were used in training (i.e., the top or bottom 6 displays in Figure 1). The remaining 6 displays (untrained) were saved to test for if-then rule learning. Figure 1 illustrates this split of the displays. Notice that the two sets of displays were counterbalanced so that within each set, each item occurred equally often as a sample (twice), correct choice (left and right), and incorrect choice (left and right). The roles of the two display sets were counterbalanced within each group.

There were 84 trials in each daily training session. Each training display was presented on 14 trials in a daily session. Acquisition of the 6 training displays continued until performance was 70% or better on all 6 training displays for two consecutive sessions. The correction procedure was then removed and training continued until the same performance criterion was met on a single session. Testing then began on the following session.

Testing—Untrained displays were tested for 10 consecutive sessions. These testing sessions consisted of 90 trials, 84 of which were the 6 training displays presented 14 times each. The remaining 6 trials consisted of the 6 untrained displays, which were each tested once per session. The order and placement of these 6 test trials was pseudorandomly assigned. Performance on test trials was reinforced identically to the training displays trials. If the pigeons learned the task by if-then rules, then performance on the untrained displays was expected to be equal to performance on training displays. If, on the other hand, the pigeons learned configural rules, then performance on the untrained displays was expected to equal chance (50%).

If pigeons fully learned the abstract concept they would transfer to everything, including the untrained displays. The test for abstract-concept learning was conducted immediately after the test for if-then rule learning. In the abstract-concept learning test, trials were constructed from novel cartoon items never before seen by the pigeons (see Figure 2). There were 94 trials per session, consisting of the 84 training displays and 10 novel transfer displays which were

pseudorandomly placed among the training displays. Each cartoon item was tested only once to avoid any learning effects that might occur if the items were repeated (e.g., Katz et al., 2007; Premack, 1978; Wright et al., 1988). Testing continued for 5 consecutive sessions. Thus, the test for abstract-concept learning consisted of 50 novel transfer displays constructed from 100 unique cartoon items (20 cartoon items per session for 5 sessions). Performance on novel transfer trials was reinforced identically to the training display trials. If pigeons fully learned the abstract concept, then performance on novel displays was expected to be equal to performance on trained displays.

Results

Figure 3 (top panel) shows mean percent correct accuracy across the 84-trial sessions for both the FR1 and FR20 groups. All pigeons rapidly learned the MTS task. The bottom panel of Figure 3 shows the mean trials to reach the performance criterion. The FR20 group reached the training performance criterion significantly faster than the FR1 group, as confirmed by an one-way Analyses of Variance (ANOVA), $F(1, 6) = 6.9, p < .05$.

The transfer results are shown in Figure 4. Performance on the trained displays did not change across the 15 total testing sessions with the untrained and novel-stimulus displays and was combined in Figure 4. Transfer performance differed across test conditions but did not change as a function of FR, as confirmed by a two-way repeated measures ANOVA of Condition (trained, untrained, novel-stimulus) $\times$ Group (FR1, FR20) yielding only a main effect of Condition, $F(2, 12) = 133.46, p < .01 \times 10^{-6}$. There was no abstract-concept learning, as novel stimulus performance (51.8%) was equivalent to chance (50%; $t(7) = .825, p = .44$). Performance on untrained displays (79.9%) was less than trained displays (95.8%; $t(7) = 7.72, p < .001$) but greater than chance performance (50%; $t(7) = 11.63, p < .01 \times 10^{-3}$). These results, along with no evidence of abstract-concept learning, indicate a mixture of configural and if-then rule learning. If subjects had learned the task based exclusively on configural training patterns, then performance on untrained displays should have been equal to chance performance. If, on the other hand, subjects learned the task based exclusively on if-then rules, then performance on untrained displays should have been equivalent to performance on the training displays.

Further analyses of the data showed some learning of the untrained testing displays across the 10 testing sessions. This result was supported by a three-way repeated measures ANOVA of Group (FR1, FR20) $\times$ Trial Type (trained, untrained) $\times$ Session (1–10) of which the only interaction to reach significance was the Trial Type $\times$ Session interaction, $F(9, 54) = 2.4, p = .022$. This interaction was due to the increase in accuracy across sessions for the untrained but not trained displays, as confirmed by separate one-way repeated measures ANOVAs over Session (1–10) for each display type, which yielded only a Session effect for the untrained displays, $F(9, 63) = 3.84, p < .002$, and only a significant linear component $F(1, 7) = 16.11, p < .006$, from a follow up trend analysis. Analyses of the first test session showed performance on untrained displays (66.7%) was less than trained displays, (92.9%; $t(7) = 7.74, p < .0002$), and greater than chance (50%; $t(7) = 3.74, p < .01$). Hence, these analyses support a mixture of configural and if-then rule learning. The learning across test sessions indicates that the pigeons were rapidly learning the new (i.e., untrained) display configurations and/or rapidly applying if-then rules for these displays.

An analysis of the concept-learning test was also conducted to see whether or not there was any learning across the five sessions of novel-stimulus testing. There was none. This conclusion was supported by a three-way repeated measures ANOVA of Group (FR1, FR20) $\times$ Trial Type (trained, novel-stimulus) $\times$ Session (1–5), which yielded only a main effect of Trial Type. The lack of learning with novel stimuli means that the novel transfer trials themselves did not foster transfer across testing. The pigeons experienced 50 novel item pairings (100 individual cartoon

items) across the 5 transfer sessions, which is like a set-size expansion. In this case, pigeons apparently need more than one trial training with new stimuli to increase their level of transfer. The same result also occurs in tests of same/different abstract-concept learning (cf. Katz & Wright, 2006; Katz et al., 2007).

Discussion

This experiment shows, for the first time, that pigeons can learn an MTS task by if-then rule learning. It also shows that two item-specific strategies, if-then rule learning and configural rule learning can co-exist and be employed at the same time to learn the MTS task without any relational learning or abstract-concept learning. The current experiment corroborates the finding of Bodily et al. (in press) that presenting stimuli from a vertical panel in the traditional manner produces results that differ from those obtained when the same stimuli are presented from the floor via a horizontal panel (Wright, 1997).

Unlike the results using a horizontal panel, the present experiment showed no evidence for abstract-concept learning, and no influence of the observing response requirement on the type of learning. With the horizontal panel, there was full abstract-concept learning with a FR20 required to the sample stimuli, full configural learning with a FR1 to sample stimuli, and no evidence of if-then rule learning at any FR value. By contrast, in the present experiment there was substantial if-then rule learning at both FR values and both groups showed the same combination of if-then and configural rule learning. Pigeons learned MTS faster as the FR was increased regardless of the stimulus panel orientation – a standard finding in MTS. However, pigeons learned faster with the vertical panel (FR1 = 1092, FR20 = 868 trials) than any group trained with the horizontal panel (FR0 = 4452, FR1 = 3297, FR10 = 2709, FR20 = 2331 trials). The findings from the present experiment show that the orientation in which the stimuli are presented radically changes the rate and type of learning that results. Thus, there appears to be a qualitative difference in the way the task is learned; that is, the learning strategies are different in these two situations.

These findings raise the question of why there is this qualitative difference between these two different settings. The answer is not obvious, but the behavior of the pigeons in these two settings may provide some clues. In the horizontal-stimulus-panel setting, pigeons typically view the stimuli from an upright position and then bend down to peck the sample and make their choice responses. In the vertical-stimulus-panel setting, pigeons typically move very close to the panel and stimuli. They remain very close to the panel and stimuli throughout the trial. These distance differences may indicate that they viewed the stimuli and display differently. For example, in the horizontal-stimulus-panel setting when the pigeons stood upright after pecking the sample they could view the whole display of sample and two comparison stimuli simultaneously. They were more deliberate in their side stimulus choice and viewed the stimuli longer. Although not video recorded, they certainly had the opportunity to look back and forth between the choices and the sample stimuli before making a choice response (see Wright, 1990 for a Markov model of such choice behavior).

The response panel orientation, in addition to the training set size, both appear to determine whether or not the MTS abstract concept will be learned. Early attempts at testing pigeon MTS concept learning failed, apparently because neither the stimulus-panel orientation nor the set size were conducive to abstract-concept learning (e.g., Berryman, Cumming, Cohen, & Johnson, 1965; Cumming & Berryman, 1961; Farthing & Opuda, 1974; Holmes, 1979). A large training set size appears to be sufficient but not necessary for pigeons to learn the abstract matching concept, as pigeons can fully learn the abstract concept with a small set size if a large sample observing response was required (Wright, 1997). The current study indicates that the observing-response requirement was not sufficient for abstract-concept learning, and either the

FR needed to be increased or accompanied by horizontal stimulus presentation, a technique that has been adopted by several other studies (e.g., Lombardi, 2007; Smirnova, Lazareva, & Zorina, 2000; Wright & Delius, 2005).

The present experiment further shows the utility in using tasks that may be learned in more than one way to investigate human and nonhuman cognition. New tactics, such as the split-set design, may help determine what subjects learn when they do not learn the relational abstract concept. We have shown here, for the first time, evidence that pigeons (or indeed any subject) can learn the MTS task via if-then rules. Moreover, this if-then rule learning strategy (which underscores that different types of learning are possible) can be accompanied by a configural learning strategy. Indeed, looking to the future, we know that pigeons trained in a similar setting eventually learn the abstract concept as the training set size is expanded sufficiently (Bodily et al., in press). Therefore, there should be a transition stage (perhaps at a stimulus set of 32 to 64 stimuli) in which a similar split-set design may show all three strategies (if-then, configural, and relational) operating at the same time.

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Figure 1.

The twelve display configurations constructed from the three cartoon items (apple, duck, grapes) used in matching-to-sample. Pigeons were trained with either the top or bottom set of six displays. Each item in each of the two training sets is counterbalanced for sample frequency and correct and incorrect comparison position. The set not used in training was used to test for if-then rule learning.

Figure 2.

Representative novel transfer cartoon items used in the 5 transfer test sessions. There were 100 unique novel cartoon items used during the transfer test.

Figure 3.

The top panel shows mean percentage correct across 84-trial sessions for pigeons trained to make 1 or 20 responses (FR1, FR20) to the sample stimulus. The bottom panel shows mean number of trials to learn the MTS task for the FR1 and FR20 groups. Error bars represent SEMs.

Figure 4.

Mean percentage correct for trained, untrained, and novel-stimulus displays for groups trained to make 1 or 20 responses (FR1, FR20) to the sample stimulus. Untrained displays refer to tests of the set of six displays not used in training. Novel-stimulus displays refer to tests with trial-unique novel cartoon items not seen in training. The dotted line represents chance performance. Error bars represent SEMs.