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EMPIRICAL VALIDATION OF A PROCEDURE TO CORRECT POSITION AND STIMULUS BIASES IN MATCHING-TO-SAMPLE

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The development of position and stimulus biases often occurs during initial training on matching-to-sample tasks. Furthermore, without intervention, these biases can be maintained via intermittent reinforcement provided by matching-to-sample contingencies. The present study evaluated the effectiveness of a correction procedure designed to eliminate both position and stimulus biases. Following key-peck training, a group of 6 pigeons had extended exposure to matching-to-sample contingencies without a correction procedure, a group of 4 pigeons was briefly exposed to a simultaneous matching-to-sample procedure to assess biases prior to exposure to the correction procedure, and a group of 5 pigeons was exposed directly to the correction procedure. The correction procedure arranged that every time an incorrect match was made, the trial configuration was repeated on the subsequent trial until a correct match was made. Extended exposure to matching-to-sample contingencies without a correction procedure was associated with reduced biases eventually for most subjects, but rapid development of near-perfect accuracy and bias-free performance was observed upon the implementation of the correction procedure regardless of the type of bias. Bias-free performance was maintained following subsequent exposure to a zero-delay MTS procedure.

Key words: position bias, stimulus bias, correction procedure, matching-to-sample, pigeons

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In a matching-to-sample (MTS) procedure, the selection of a stimulus from an array of stimuli (hereafter, comparison stimuli) is reinforced conditionally upon the presence of another stimulus (hereafter, sample stimulus). Correct matching is determined either by some shared property of the sample and comparison stimuli, as in the case of identity or oddity matching (e.g., Weinstein, 1941), or by an arbitrary relation programmed by the experimenter, as in the case of symbolic or arbitrary matching (e.g., Carter & Eckerman, 1975).

The MTS task is a procedure often employed to assess the acquisition, performance, and maintenance of conditional discriminations and has been used by a host of researchers in the study of human and nonhuman animal behavior. The basic characteristics of the MTS procedure were cataloged over four decades ago (e.g., Blough, 1959; Cumming & Berryman, 1961; 1965). Currently, MTS tasks in various forms serve to assess complex operant relations including stimulus equivalence (e.g., Sidman, 1994), and in the case of delayed MTS, forgetting functions (e.g., McCarthy & White, 1987).

One noted problematic feature inherent in preliminary training and the acquisition of MTS performance is a susceptibility to position and stimulus biases. Early reinforcement history may engender biases even when the programmed contingencies suggest there should be equal preference in response allocation. It is unclear how ubiquitous the occurrences of biases are in early MTS training, but it has been our experience that the development of position and stimulus biases is commonplace during the initial training of MTS. Indeed, in one of the first reports of a systematic analysis of the acquisition of MTS performance, Cumming and Berryman (1961) noted that all subjects quickly developed a position bias.

In a chapter on conditional stimulus control, Mackay (1991) noted the prevalence of position and stimulus biases during MTS training and attributed the maintenance of this behavior to intermittent reinforcement. Mackay gave the example of a pigeon engaging in an MTS task in a standard three-key

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operant-conditioning chamber, and pointed out that a right key bias, for example, may be maintained indefinitely because it ''produces reinforcement on half of the trials scheduled because the comparison stimulus that matches the sample alternates irregularly from left to right. The experimenter-specified contingencies thus may provide sufficient reinforcement to maintain highly persistent right-key responding (p. 312).'' Similar intermittent reinforcement contingencies could also be responsible for the maintenance of a stimulus bias. Mackay briefly outlined a correction procedure designed to eliminate these biases. In the correction procedure, each error (i.e., response to an incorrect comparison stimulus) is followed by repetition of the trial configuration on the subsequent trial. Although Mackay provided no data on the effectiveness of the correction procedure in eliminating biases, he stated, ''Exposure to a correction procedure can help to break up existing position and stimulus preferences, as well as other stereotyped error patterns that may occur. When used from the beginning of training, these contingencies may prevent the development of systematic error behavior (p. 312).''

A review of the literature suggested that although there has not been a formal investigation of the efficacy of the correction procedure described above, it is commonly employed. We examined the Methods sections of 155 peer-reviewed publications with the keywords *matching-to-sample* and *pigeons*. Out of the 155 articles, 43 reported using a correction procedure in which the trial configuration repeated after an incorrect response; the oldest we found was by Blough (1959). There were two common ways in which the correction procedure was used. In many studies it was used during the training of conditional discrimination performance but was not programmed in the testing phase or experiment proper (e.g., Godfrey & Davison, 1998; Grant, 1975; Kuno, Kitadate, & Iwamoto, 1994; McCarthy & Voss, 1995; McClure, Saulsgiver, & Wynne, 2005; Nevin, Milo, Odum, & Shahan, 2003; Wright, 1997). In other studies, however, the correction procedure was kept in place after initial training, but the repeated trials were not included in the analyses of performance (e.g., DeMarse & Urcuioli, 2005; Kelly & Grant, 2001; Lattal 1979; Pisacreta, 1990; Shimp, 1981; Urcuioli, DeMarse, & Lionello-DeNolf, 2001).

Surprisingly, despite the relatively high prevalence of employment of correction procedures for MTS training, to our knowledge, no data on their effects have been published. Given the noted frequency of use of correction procedures, therefore, the purpose of the present study was to conduct an empirical evaluation of a correction procedure to determine its effectiveness in eliminating both position and stimulus biases.

METHOD

Subjects

Fifteen experimentally naïve male White Carneau (*Columba livia*) pigeons, approximately 1 year old, were obtained from Double-T Farms, Glenwood, Iowa, and were maintained at approximately 85% of their free-feeding weights by postsession feeding as needed. The animals were housed in individual cages, in a temperature- and humidity-controlled colony room, with exposure to a 16:8-hr light/dark cycle. Water and grit were available continuously in the birds' home cages.

Apparatus

The experiment was conducted in a sound- and light-attenuating BRS/LVE pigeon chamber with inside dimensions measuring 35 cm high, 30 cm long, and 35 cm deep. One side wall (the intelligence panel) contained a houselight, three horizontally arrayed response keys (2.5 cm in diameter) and a 6-cm by 5-cm opening for access to a solenoid-operated hopper filled with mixed grain. The opening was located 10 cm above the floor and centered below the center key. During each feeder operation, the aperture was illuminated, and all other lights in the chamber were extinguished. The center key was horizontally centered on the intelligence panel 25 cm above the floor. The two side keys were located 8 cm to the left and right of the center key. Each key could be transilluminated red, green, or white, and a peck with a force of at least 0.15 N counted as a response and was accompanied by a 30-ms feedback tone (2900 Hz) via the operation of a Mallory Sonalert^{TM}. To mask extraneous sounds, white noise at approximately 95 dB was present in the room in which sessions were conducted. Scheduling of experimental events and data collection were controlled via a dedicated computer system (Palya & Walter, 1993).

Procedure

Each pigeon was first trained to eat food from the hopper and then trained by shaping (Catania, 1998) to peck the center key (illuminated white). After the pigeon pecked the center key reliably when lit, shaping was employed to induce it to peck the right and left key (illuminated white). After the pigeon was pecking all three keys reliably when lit, one of the three keys was illuminated red or green and pecks to the illuminated key resulted in access to grain. Additional shaping was used if necessary, and training trials continued until the pigeon reliably pecked each of the three keys when they were illuminated either red or green.

All 15 pigeons were next trained on the MTS task using a simultaneous MTS procedure. Specifically, discrete trials began with the illumination of the houselight and the center (sample) key with either a red or green hue. A single peck to the sample key illuminated the two side (comparison) keys with matching and nonmatching hues (i.e., sample and comparison keys were illuminated simultaneously). A single peck to the side key illuminated with the same color as the sample key (i.e., the correct match) turned off the houselight, the sample key, both comparison keys, and raised the food hopper for 3 s followed by a 10-s intertrial interval (ITI). An intertrial interval was employed because previous research has shown that ITIs improve accuracy of pigeon MTS performance (e.g., Thomas, 1979; White, 1985). A single peck to the nonmatching comparison key (i.e., the incorrect response) turned off all lights in the chamber and initiated a 13-s ITI. The 10-s ITI (plus 3-s hopper access) following a correct match, and 13-s ITI following an incorrect match ensured equivalent times between trial onsets following a correct or incorrect match.

A two-color (red [R] and green [G]), two-comparison MTS procedure yields four possible trial configurations (RRG, GRR, RGG, GGR). The computer arranged the presentation of these configurations on each trial in a quasirandom order. Specifically, each of the four configurations was presented before any configuration could be repeated (i.e., random selection without replacement). This procedure guarantees that the maximum number of consecutive identical trials is two, the maximum number of consecutive trials on which the same comparison color is correct is four, and the maximum number of consecutive trials on which the same side key is correct is also four.

No-Correction (control) group. Six subjects (268, 800, 808, 876, 930, and 939) were exposed to 30 daily sessions consisting of 48 programmed trials per session without a correction procedure. This group was included to ascertain whether extended exposure alone would be sufficient to decrease biases and to increase accuracy.

Mid-Course-Correction group. In order to determine each subject's bias before evaluation of the correction procedure, a second group of 4 subjects (711, 809, 992, and 994) was exposed to four daily sessions consisting of 72 programmed trials and no correction procedure. A correction procedure was then implemented on the fifth session. The correction procedure was programmed as follows. Each time a subject made an incorrect response (i.e., pecked the nonmatching comparison), the trial configuration was repeated, after the ITI, until a correct response was made. For example, if the pigeon pecked the right key in the presence of an RRG configuration, the 13-s ITI would begin and the RRG configuration would be presented again on the subsequent trial, and would continue to be presented after each ITI until the pigeon pecked the correct (i.e., left) comparison key. Each session ended upon completion of 72 correct matches. No session time limit was programmed. Each pigeon was exposed to this correction procedure for 20 daily sessions (i.e., 1440 correct matches).

Correction-from-Outset group. The purpose of this third group was to evaluate the correction procedure programmed from the beginning of MTS training. Five subjects (4, 34, 682, 846, and 848) were exposed directly to the correction procedure described above following keypeck training. Each daily session for these subjects consisted of 48 programmed trials, and sessions ended upon completion of 48 correct matches, with no imposed session time limit. Each pigeon was exposed to this correction procedure for 30 daily sessions (i.e., 1440 correct matches).

Following exposure to the protocol above, the 9 subjects in the Mid-Course- Correction group and the Correction-from-Outset group were placed on a zero-delay (also known as a successive) MTS procedure. In this condition, a single peck to the center key turned off the sample and immediately illuminated both comparison keys. The consequences for pecking the matching or nonmatching key remained the same as before. This condition was designed to make the MTS task more difficult in order to ascertain whether the effects of the correction procedure would be maintained or if biases would return. Furthermore, this test of the correction procedure's integrity was important to assess because studies that employ the delayed MTS procedure often expose subjects to a zero-delay MTS task following accurate performance on a simultaneous MTS procedure (e.g., Berryman, Cumming, & Nevin, 1963; Blough, 1959). This condition lasted for 10 sessions for the subjects with 72 trials per session and 15 sessions for the subjects with 48 trials per session (i.e., 720 trials).

RESULTS

All 15 subjects learned to eat from the hopper and peck all three keys first illuminated white and then either red or green within approximately 1 to 3 hours of training. No systematic between-subject differences were noted, but each pigeon took a different amount of time before key pecks were reliably observed.

Figure 1 presents the accuracy of performance for each trial configuration for the No-Correction (Control) group exposed to 30 sessions (i.e., 1440 trials) of simultaneous MTS without a correction procedure. Subjects 800, 808, and 876 displayed a right side bias; Subjects 268, 939, and 930 displayed a left side bias. Bias was evident in the first session for all 6 subjects. Biases decreased, and increased accuracies were observed for 5 out of 6 subjects after extended exposure. The amount of exposure before biases began to decrease, however, varied between subjects, the shortest being eight sessions for 808. Four out of 6 subjects (268, 800, 808, and 939) were performing with 90% accuracy or greater after 30 sessions of exposure to the MTS contingencies. Subject 876's bias was no longer observed after approximately 10 sessions when the subject began performing in a highly variable, inaccurate fashion. Subject 930's left side bias was observed for the all 30 sessions. Extended exposure to simultaneous MTS contingencies without a correction procedure therefore led to highly accurate, bias-free performance in some subjects, however, the amount of exposure necessary before accurate performance developed varied among subjects.

Figure 2 presents the accuracy of performance for each trial configuration for the Mid-Course-Correction group exposed to four sessions (288 trials) of simultaneous MTS without a correction procedure. Subject 711 displayed a right side bias. Subject 809, 992, and 994 displayed a left side bias. Again, bias was evident in the very first session for all 4 subjects, and in the two cases where it was less extreme, it became more extreme across successive sessions.

Figure 3 presents the number of trials needed to complete each session once the correction procedure was implemented for the Mid-Course-Correction group and the Correction-from-Outset group. For all 9 subjects, many trials were required on the first day of exposure to the correction procedure, but the number of trials repeated was significantly reduced on the second session. The number of trials was further reduced across sessions for all subjects, and the development of near-perfect performance was observed.

Table 1 presents the number of repeated trials by configuration in the first session under the correction procedure. An analysis of trial configuration repeats in the first session confirmed the side biases of subject 711, 809, 992, and 994, with fewer trial-configuration repeats on their respective biased side.

Table 2 presents a within-session analysis of the effects of implementing the correction procedure for the Mid-Course-Correction group. Prior to the correction procedure, all 4 subjects were making the same percentage of errors during the first half of the session relative to the second half. Effects of the correction procedure were rapid. An assessment of percent correct during initial exposure to each trial configuration indicated fewer errors during the second half of the session, showing not only that implementation of the

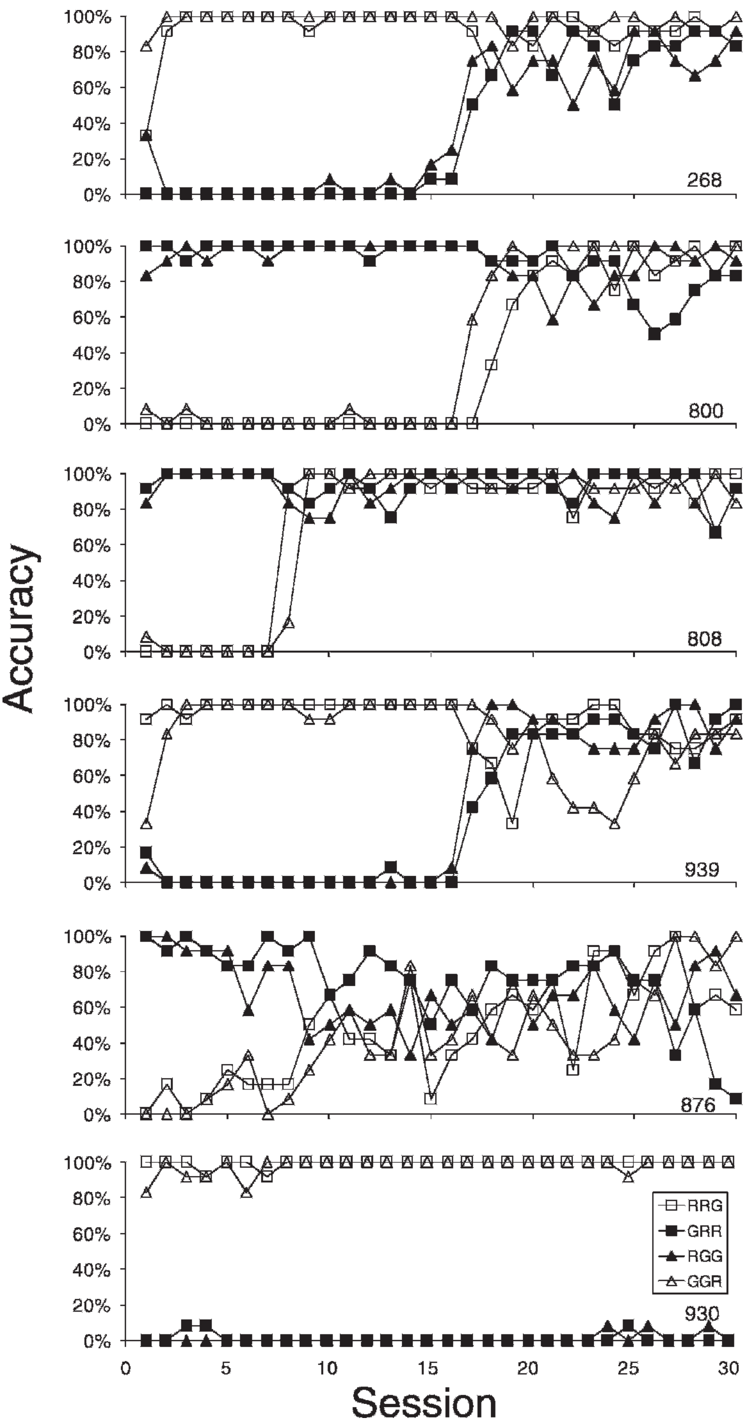

Fig. 1. Accuracy by trial configuration of simultaneous MTS performance without the correction procedure for the No-Correction (Control) group. Open symbols indicate the left comparison is correct, closed symbols indicate the right comparison is correct.

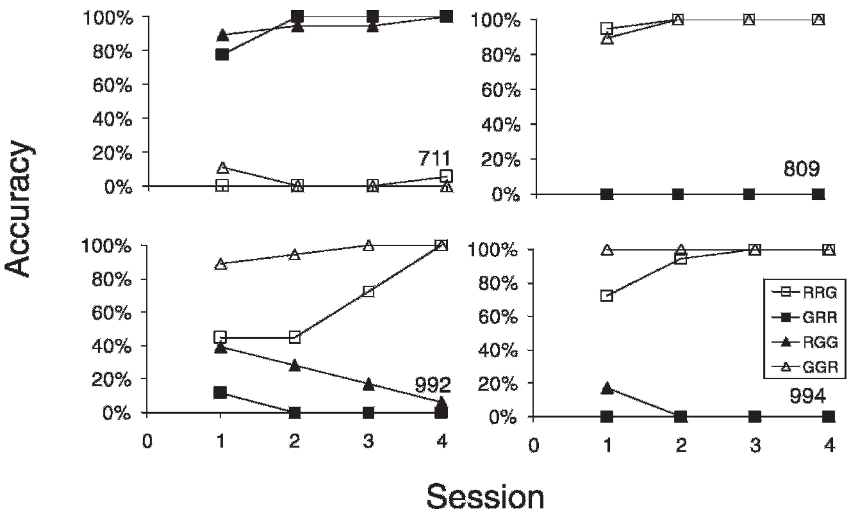

Fig. 2. Accuracy by trial configuration of the first four sessions of simultaneous MTS performance without the correction procedure for the Mid-Course- Correction group. Open symbols indicate the left comparison is correct, closed symbols indicate the right comparison is correct.

correction procedure produced rapid effects on accuracy (see the second session in Figure 3 for all subjects), but also that it was not likely that simple extended exposure to the MTS procedure that was responsible for improved accuracy. That is, there was no evidence in the fourth, and last, session without the correction procedure that accuracy was beginning to improve.

Subjects 4, 34, 682, 846, and 848 (i.e., Correction-from-Onset group) were never exposed to the simultaneous MTS task without a correction procedure in place; however, performance on the first session under the correction procedure was comparable to the other group's performance in the first session of simultaneous MTS without a correction procedure, namely, highly accurate performance on two trial configurations and highly inaccurate performance on the other two trial configurations. In addition, their biases can be derived from an analysis of their errors on the first session under the correction procedure. An assessment of trial-configuration repeats indicated that Subjects 4 and 34 displayed a green-key bias, 682 and 848 displayed a left side bias, and 846 displayed a red-key bias (see Table 1).

Figure 4 presents trial configuration accuracy under the zero-delay MTS procedure for the two groups of pigeons exposed to the procedure. A decrease in accuracy across trial configurations, at least for some configurations, was noted for several subjects upon implementation of the zero-delay MTS task; however, no consistent position or stimulus bias was observed in any of the subjects. Subjects 809 and 846 displayed a left side bias initially, but in both cases, the bias diminished within three sessions without intervention. By condition's end (i.e., 720 trials), 8 of the 9 subjects were performing with an overall accuracy above 85%.

An assessment of potential between-group differences of the subjects exposed to 72 trials per session and the subjects exposed to 48 trials per session revealed no significant differences in the number of trials required to reach highly accurate performance under the correction procedure. An analysis of the number of trials needed to reach 85% accuracy in a session (repeating 12 or fewer trials for the 72-trials-per- session group; repeating 8 or fewer trials for the 48-trials-per-session group) indicated that the 72-trials-per-session group reached 85% correct after an average of 342 trials, whereas the 48-trials-per-session group reached 85% correct after an average of 490 trials. This difference, however, was not statistically significant, t (7) $= -1.018$, $p = .343$. In addition, no significant between-group difference was observed in the disruption of performance upon exposure to the zero-delay condition. The 72-trials-per-

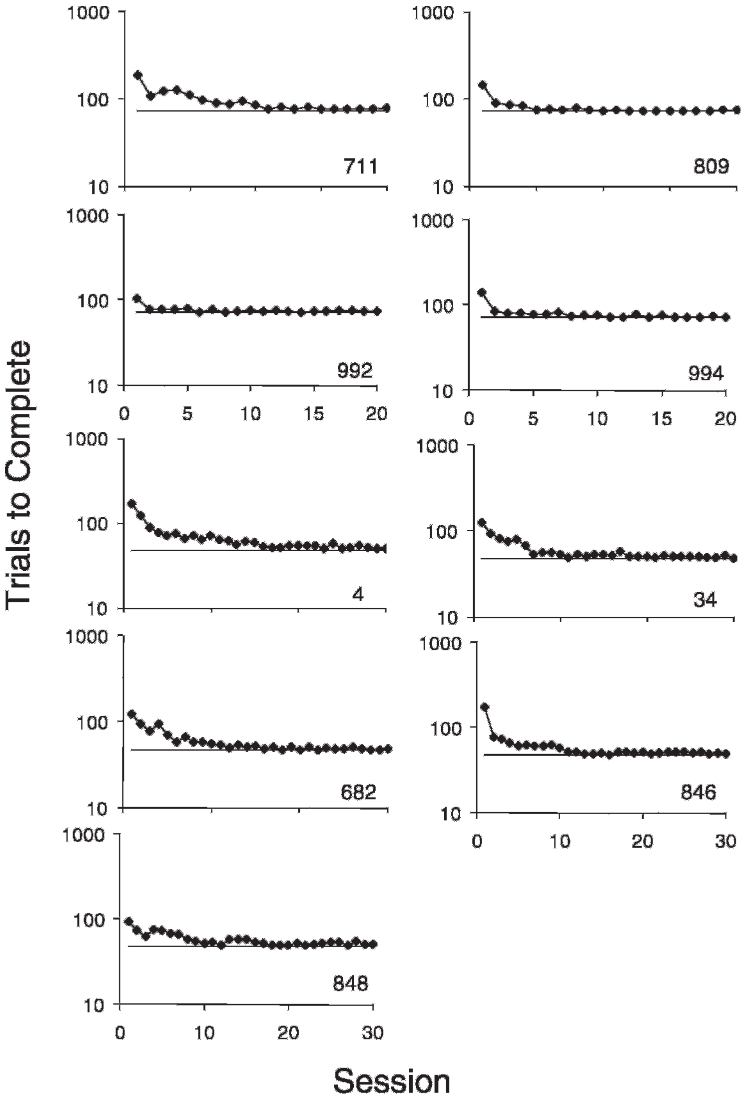

Fig. 3. Number of total trials per session under the correction procedure for the Mid-Course-Correction Group and the Correction-from-Onset group. Solid horizontal line indicates number of correct trials required to complete a session. Y-axis is logged to normalize proportional change across subjects.

session group performed with a mean accuracy of 83.86% on the first 48 trials of the first session of the zero-delay condition, whereas the 48-trials-per-session group performed with a mean accuracy of 80.00% on the first session. This difference was also not statistically significant, t (7) = 1.074, p = .334.

Finally, the 2 subjects from the No-Correction (Control) group that did not display accurate MTS performance were exposed to the correction procedure immediately following the 30 sessions. Rapid improvements in accuracy were associated with the change in procedure for both pigeons in a fashion very similar to that of the subjects in the Mid-Course-Correction group and the Correction-from-Onset group (data not shown). This suggests that this correction procedure can be effective in engendering accurate performance even after many sessions without intervention and when poor accuracy is not associated with a particular position or stimulus bias.

Table 1

Number of repeated trials by configuration on the first session under the correction procedure.

Subject	RRG	GRR	RGG	GGR
711	51	11	23	31
809	3	56	9	3
992	5	10	16	3
994	3	6	57	5
4	42	34	22	19
34	25	27	14	7
682	13	28	25	6
846	20	14	48	44
848	6	13	14	10

DISCUSSION

The present study assessed the effectiveness of a matching-to-sample correction procedure designed to eliminate position and stimulus biases of pigeons under a simultaneous MTS procedure. Exposure to the correction procedure was associated with a rapid reduction in the number of errors regardless of the specific type of bias for all subjects. When subjects were later exposed to a zero-delay MTS procedure, biases remained minimal despite temporary decreases in accuracy, suggesting that the bias-reducing functions of the correction procedure produced enduring effects.

Interestingly, after initial key peck training, all 15 subjects displayed a bias of some sort, and among the 15 subjects, each possible type of bias was observed (i.e., left, right, red, and green). In the absence of a larger sample of subjects, it is still unclear how ubiquitous the development of biases is in the training of matching-to-sample tasks. Regardless, it should be noted that we did not attempt to engender biases of any sort, or did we do anything special to try to avoid them. Each pigeon was trained by the same person (the first author) using the protocol described above, and biases were observable only upon implementation of the MTS procedure. So even if our key peck training protocol was somehow flawed or not optimal, it did not lead to any specific biases.

It is possible that early histories of reinforcement engendered each subject's bias. There was no differentiated behavior during key peck training that was detectable to the experimenter, but perhaps there was differentiated behavior exhibited by the subject. Several possibilities exist. A quicker and more robust development of pecks to the key illuminated green may have occurred because it was brighter (relative to the red key) and thus more salient or closer in appearance to the original training stimulus (i.e., white key) leading to a green-key bias; presenting the red key light first (before exposure to the green key light) may have had long term single-trial learning effects leading to a red-key bias; a tendency to stand left of center because of the aversive nature of the chamber door (which was to the right) may have engendered a left side bias; or perhaps pigeons have a sort of ''laterality'' that led to a preference for the right side of a chamber. All of these hypotheses are testable, but further experimentation will be needed to examine them.

In conclusion, the present data indicate that a trial–repeat correction procedure was associated with relatively rapid development of conditional stimulus control in a matching-to-sample procedure, thus validating a commonly held assumption. The results also suggest that such a correction procedure can rapidly reduce position and stimulus biases that may be present during initial training on a matching-to-sample procedure. Extended exposure to the MTS contingencies without correction resulted in reduction of bias in some subjects, but many sessions were required, and the

Table 2

Percent of correct trials during the first and second half of the last session without correction and first session with correction.

Subject	Last Session w/o Correction		First Session on Correction	
	First ½	Second ½	First ½	Second ½
711	50.0%	52.8%	27.8%	44.4%
809	50.0%	50.0%	55.6%	69.4%
992	52.8%	50.0%	63.9%	86.1%
994	50.0%	50.0%	63.9%	88.9%

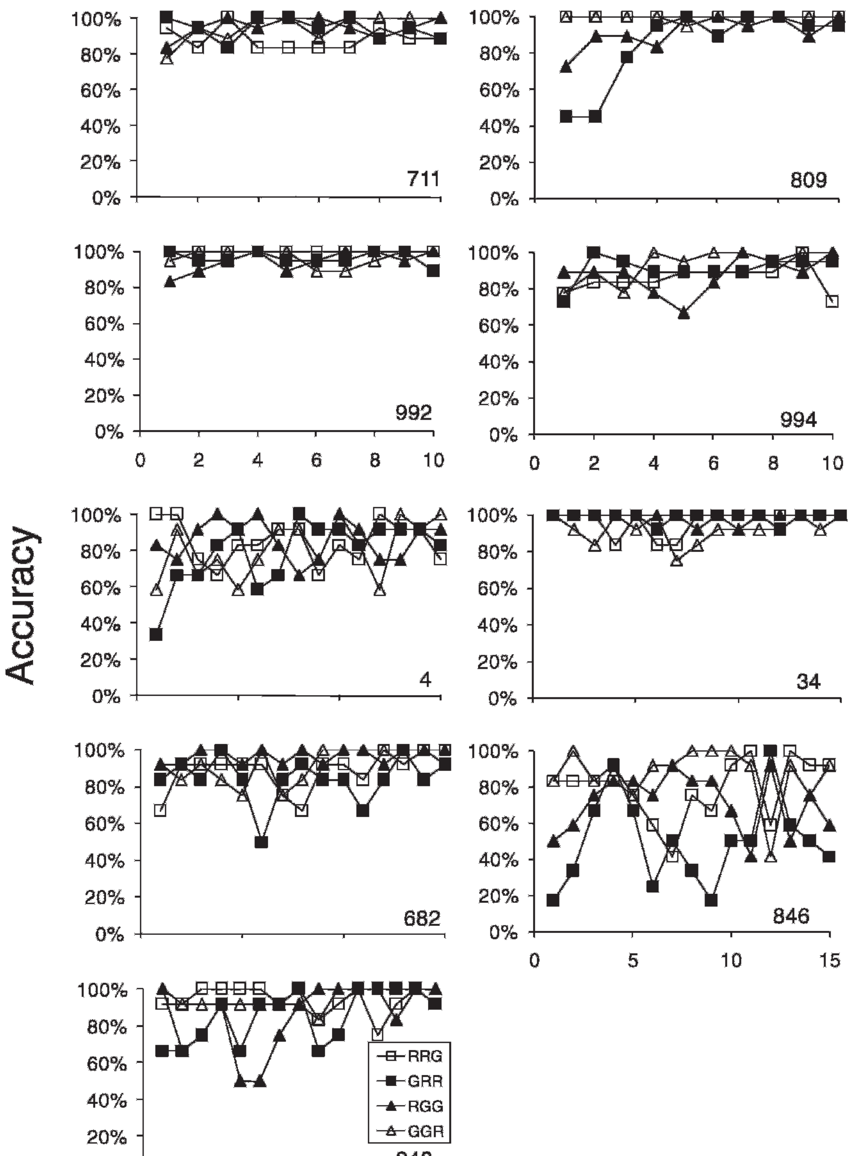

Fig. 4. Accuracy by trial configuration of performance each session under the zero-delay MTS procedure for the Mid-Course-Correction group and the Correction-from-Onset group.

number of sessions required varied widely between subjects. This disparate history in the number of sessions displaying a given bias could prove problematic in later experimental conditions and promote intersubject variability. Employing a correction procedure, therefore, may have the added benefit of producing histories that are more similar across subjects. Furthermore, because no significant differences were found between the effects of the correction procedure employed from the outset versus after sessions of training without correction, these data suggest that programming a correction procedure from the outset of matching-to-sample training may be an optimal standard practice.

REFERENCES

Berryman, R., Cumming, W. W., & Nevin, J. A. (1963). Acquisition of delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior*, *6*, 101–107.

Blough, D. S. (1959). Delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior*, *2*, 151–160.

Carter, D. E., & Eckerman, D. A. (1975). Symbolic matching by pigeons: Rate of learning complex discriminations predicted by simple discriminations. *Science*, *187*, 662–664.

Catania, A. C. (1998). *Learning*. (4th ed.). New Jersey: Prentice Hall.

Cumming, W. W., & Berryman, R. (1961). Some data on matching behavior in the pigeon. *Journal of the Experimental Analysis of Behavior*, *4*, 281–284.

Cumming, W. W., & Berryman, R. (1965). The complex discriminated operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stimulus Generalization* (pp. 284–330). Stanford, CA: Stanford University Press.

Demarse, T. B., & Urcuioli, P. J. (2005). Control of matching by differential outcome expectancies in the absence of differential sample-outcome associations: a serial compound view. *Journal of Experimental Psychology: Animal Behavior Processes*, *31*, 449–466.

Godfrey, R., & Davison, M. (1998). Effects of varying sample- and choice-stimulus disparity on symbolic matching-to-sample performance. *Journal of the Experimental Analysis of Behavior*, *69*, 311–326.

Grant, D. S. (1975). Proactive interference in pigeon short-term memory. *Journal of Experimental Psychology: Animal Behavior Processes*, *1*, 207–220.

Kelly, R., & Grant, D. S. (2001). A differential outcomes effect using biologically neutral outcomes in delayed matching-to-sample with pigeons. *The Quarterly Journal of Experimental Psychology B: Comparative and Physiological Psychology*, *54*, 69–79.

Kuno, H., Kitadate, T., & Iwamoto, T. (1994). Formation of transitivity in conditional matching to sample by pigeons. *Journal of the Experimental Analysis of Behavior*, *62*, 399–408.

Lattal, K. A. (1979). Reinforcement contingencies as discriminative stimuli: II. Effects of changes in stimulus probability. *Journal of the Experimental Analysis of Behavior*, *31*, 15–22.

Mackay, H. A. (1991). Conditional stimulus control. In I. H. Iversen & K. A. Lattal (Eds.), *Techniques in the behavioral and neural sciences: Vol. 6. Experimental analysis of behavior* (Part 1, pp. 301–350). Amsterdam: Elsevier.

McCarthy, D., & Voss, P. (1995). Delayed matching-to-sample performance: Effects of relative reinforcer frequency and of signaled versus unsignaled reinforcer magnitudes. *Journal of the Experimental Analysis of Behavior*, *63*, 33–51.

McCarthy, D., & White, K. G. (1987). Behavioral models of delayed detection and their application to the study of memory. In M. L. Commons, J. E. Mazur, J. A. Nevin, & H. Rachlin (Eds.), *Quantitative analyses of behavior: Vol. 5. Reinforcement value: The effect of delay and intervening events*. Cambridge, MA: Ballinger.

McClure, E. A., Saulsgiver, K. A., & Wynne, C. D. (2005). Effects of D-amphetamine on temporal discrimination in pigeons. *Behavioral Pharmacology*, *16*, 193–208.

Nevin, J. A., Milo, J., Odum, A. L., & Shahan, T. A. (2003). Accuracy of discrimination, rate of responding, and resistance to change. *Journal of the Experimental Analysis of Behavior*, *79*, 307–321.

Palya, W. L., & Walter, D. E. (1993). A powerful, inexpensive experiment controller for IBM PC interface and experiment control language. *Behavior Research Methods, Instruments & Computers*, *25*, 127–136.

Pisacreta, R. (1990). Symbolic matching-to-sample employing pictorial stimulus classes. *The Psychological Record*, *40*, 411–428.

Shimp, C. P. (1981). The local organization of behavior: discrimination of and memory for simple behavioral patterns. *Journal of the Experimental Analysis of Behavior*, *36*, 303–315.

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston, MA: Authors Cooperative.

Thomas, J. R. (1979). Matching-to-sample accuracy on fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior*, *32*, 183–189.

Urcuioli, P. J., DeMarse, T., & Lionello-DeNolf, K. M. (2001). Assessing the contributions of S-O and R-O associations to differential-outcome matching through outcome reversals. *Journal of Experimental Psychology: Animal Behavior Processes*, *27*, 239–251.

Weinstein, B. (1941). Matching-from-sample by rhesus monkeys and children. *Journal of Experimental Psychology*, *31*, 195–213.

White, K. G. (1985). Characteristics of forgetting functions in delayed matching to sample. *Journal of the Experimental Analysis of Behavior*, *44*, 15–34.

Wright, A. A. (1997). Concept learning and learning strategies. *Psychological Science*, *8*, 119–123.

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